APPENDIX B

MSW COLLECTION, TRANSPORTATION, AND SEPARATION

NREL Notes

Appendix B: MSW Collection, Transportation, and Separation

The estimates in this appendix represent the inputs and emissions that would result from producing enough biomass from municipal solid wastes (MSW) to supply a 2,000 tpd ethanol production facility. One location was modeled for the year 2000.

The ethanol production facility, described in Appendix C, Biomass Conversion, produces two products: denatured ethanol and electricity. The inputs and emissions of ethanol production should be allocated between the two products. The proportion of ethanol and electricity produced (on a Btu value assuming a heat rate of 10400 Btu/kWh) was 87 percent and 13 percent, respectively.

This allocation is not shown in this appendix nor is it accounted for in Appendix C. However, this allocation is reflected in the fuel cycle analysis reported in *Fuel Cycle Evaluations of Biomass Ethanol and Reformulation Gasoline, Volume I, Summary Report.* The inputs and outputs of MSW collection, transportation, and separation are allocated between the two products ultimately produced--ethanol and electricity--based on the allocations shown above. Thus tables A and J, in Volume I, show the fraction of biomass production and transportation that is allocated to ethanol fuel cycle.

Emissions of heavy metals, shown in this appendix, were estimated using the minimum uncontrolled air emission data presented in Table B-15. This data was collected at a MSW sorting/separation facility operating 8 hours per day at a capacity of 12 tons of MSW feed per day. The sorting/separation facility described in this appendix operates 24 hours per day at a capacity of 3800 tons per day. Heavy metal air emissions shown in Tables A and J, in Volume I: Summary Report, were obtained by multiplying the data from Table B-15 times the ratio of the large capacity to the small capacity plant. The allocations, described above, were applied to these new calculations.

APPENDIX B

MSW COLLECTION, TRANSPORTATION, AND SEPARATION

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APPENDIX B
MSW COLLECTION, TRANSPORTATION, AND SEPARATION

B.1 Municipal Solid Waste Location

B.1.1 Assumptions/Rationale

B.1.1.1 Assumptions

This biomass-to-ethanol total energy cycle (TEC) analysis assumes an ethanol conversion facility requiring 2,000 tons per day (TPD) on a dry basis of cellulosic/organic feedstock. The chosen site of the ethanol conversion facility in this analysis is in or around Peoria, Illinois. This characterization assumes that the feedstock required for this ethanol facility will be unsorted curbside-collected MSW and that all current recycling and composting efforts as well as those projected for the year 2000, will not be included in the waste stream. The ethanol conversion facility requires a feedstock that is shredded to a size of one-inch consisting of only cellulosic and organic materials with 19.0% water content. Since unsorted MSW contains elements besides cellulosic and organic matter, such as ferrous and nonferrous metals, plastics, etc., sorting/preparation facilities will have to process well above 2,000 TPD of raw MSW (dry basis) in order to achieve the required amounts. Additionally, system losses stemming from recovery inefficiencies (sorting/preparation stage), moisture content, and handling and transport, increase the amount of raw MSW that must be collected (3,840 wet TPD in the year 2000) in order to deliver the required 2,000 TPD. Due to the large volume of MSW required per day, Chicago and the county that surrounds Chicago (Cook County) were chosen as the target MSW collection location.

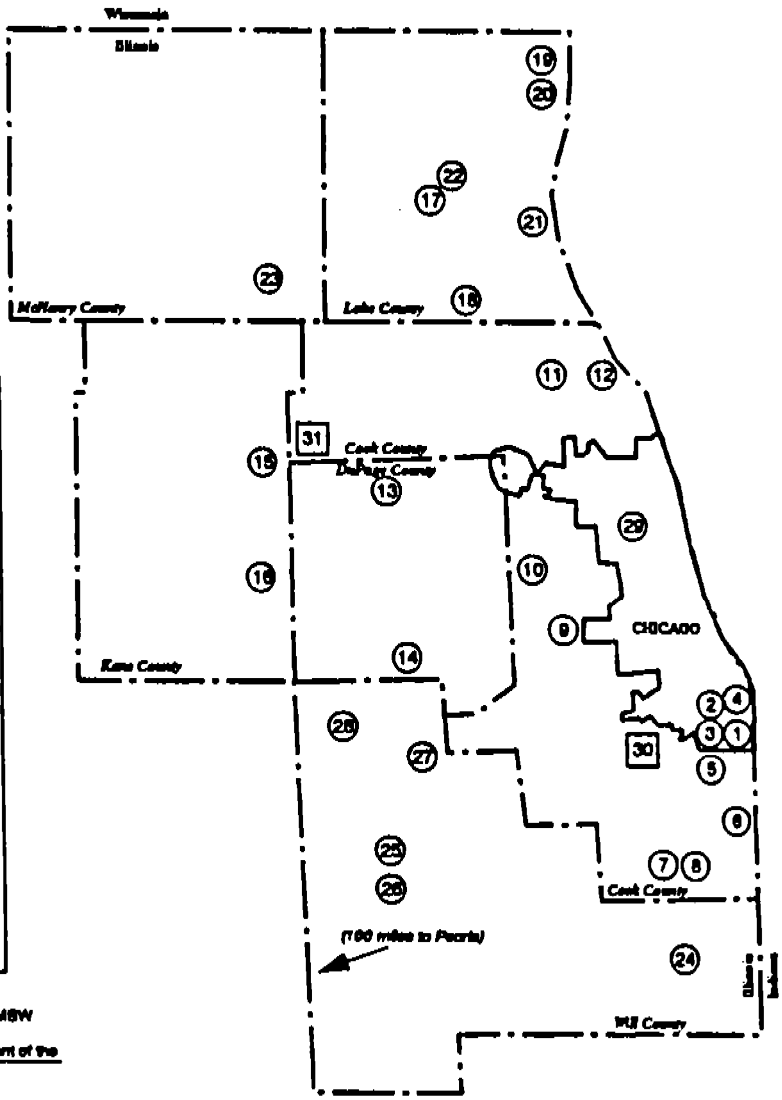
B.1.1.2 Rationale

Chicago and Cook County are the largest population centers closest to Peoria, Illinois, with a well established infrastructure of roads and railroads linking the two regions. Chicago is a large city that is approximately 225 square miles with an average density of 13,500 persons per square mile.[1] The surrounding Cook County has a population over 2 million people. While MSW collection is derived from a relatively small area, MSW disposal for Chicago and Cook County currently extends over a 50 mile radius of Chicago (Figure B-1).[2] This average distance is expected to increase due to the closing of several landfills and transfer stations in the next 10 years (Figure B-2).

B.1.1.3 Chicago and Cook County MSW Generation

B.1.1.3.1 Chicago

Chicago's population for 1990 was estimated at a little over 3.03 million. Total wastes for 1990 were just under 4.0 million tons. Of the 4.0 million tons, commercial/industrial wastes made up



MAP #	FACILITY NAME	OPERATOR
1.	CID #2	Waste Management
2.	Land & Lakes #3 (122nd St)	Land & Lakes Co.
3.	Land & Lakes #1 & 2(138th St)	Land & Lakes Co.
4.	Paxton #2	Stryker Int'l.
5.	Land & Lakes Dolton	Land & Lakes Co.
6.	Lansing/Sexton	John Sexton Contractors
7.	Fitz-Mar, Chicago Heights	Fitz-Mar Inc.
8.	Chicago Heights Refuse Depot	Chicago Heights Refuse Depot Inc.
9.	Summit/American Grading	American Grading Co.
10.	Hillside/Sexton #2	Congress Development Inc.
11.	Lake Landfill	Waste Management
12.	Winnetka Municipal	Village of Winnetka
13.	Mallard Lake	Browning-Ferris Industries
14.	Greene Valley	Waste Management
15.	Woodland	Waste Management
16.	Settlers Hill	Waste Management
17.	Grayslake/ARF	ARF Landfill Corp.
18.	Land & Lakes Wheeling	Land & Lakes Co.
19.	Winthrop Harbor/BFI #2	Browning-Ferris Industries
20.	Zion Municipal #2	City of Zion
21.	Lake Bluff Municipal #2	Village of Lake Bluff
22.	Lake County Grading	Lake County Grading Co.
23.	McHenry County/Meugler	Crystal Lake Disposal Co.
24.	Beecher/Sexton	Beecher Development Co.
25.	CDT/Joliet	CDT Landfill Corp.
26.	ESL	ESL Inc.
27.	Land & Lakes Romeoville	Land & Lakes Co.
28.	Wheatland Prairie	Waste Management
29.	Northwest Waste-to-Energy	City of Chicago
*30.	Robbins Waste-to-Energy	Reading Energy Co.
*31.	NW Cook County Balefill	SWANCC

* Pending; State development permit issued. 1/18/91

1/ All of these facilities currently handle fractions of Cook County and Chicago's MSW

SOURCE: Northeastern Illinois Planning Commission, Solid Waste Needs Assessment of the Cook County Planning Area, June 1991.

Source: Northeastern Illinois Planning Commission, Solid Waste Needs Assessment for the Cook County Planning Area, June 1991.

Figure B-1. Disposal Facilities in Northeastern Illinois Permitted to Receive Municipal Solid Waste, 1990[1]

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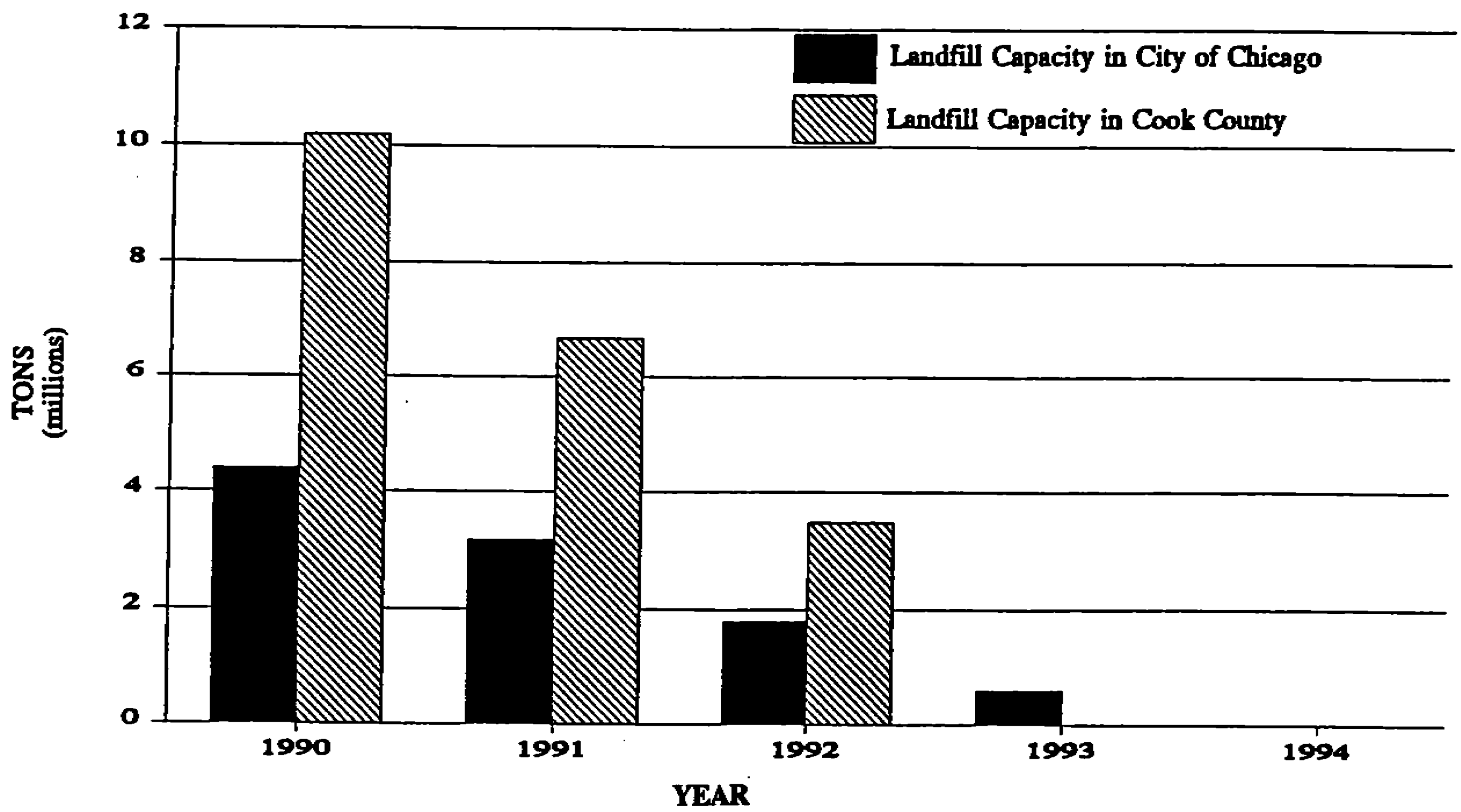
[1] All of these facilities currently handle fractions of Cook County and Chicago's MSW



[2] Based on reported remaining capacity and gate volume receipts with a 600 lb/cy average gate density. Reported landfill capacity and reported gate volume receipts based on the October 1990 Illinois EPA Fourth Annual Report on Available Disposal Capacity.

[3] Reported gate volume receipts for landfills with no reported remaining capacity after 1990 are assumed to go to the other landfills within the City of Chicago and Cook County that will have remaining capacity past 1990.

Source: HDR Engineering, Inc., Solid Waste Management Plan for City of Chicago, Volume I, August 22, 1991. pp. 2-12.

Figure B-2. Chicago Area Landfill Capacity Depletion [2,3]

just under 50% of total MSW, with low and high density residential wastes accounting for over 42%.[3] Only the residential waste (minus bulky waste), which is projected to generate 3,496 tons/day of waste in the year 2000 (Section B.2), is considered for Chicago. Commercial and industrial wastes (which have a high cellulosic and organic content) would be highly desirable feedstocks for a waste-to-ethanol process, however, high quality data for these waste streams were unavailable, and thus, could not be included in this analysis.

B.1.1.3.2 Cook County

The 1990 population of Cook County (excluding Chicago) was 2.34 million and is forecasted to reach 2.40 million by 2000. The waste stream considered for Cook County includes residential and commercial/industrial MSW (minus metal shavings and sawdust wastes from industrial processes) and is estimated to yield 2.37 million tons/yr of MSW (6,501 tons/day) in 1990 and 2.21 million tons/year (6,053 tons/day) in 2000.[4] Inclusion of Chicago's commercial and industrial wastes (if the data were available) would greatly reduce, if not completely eliminate, the amounts of MSW required from Cook County.

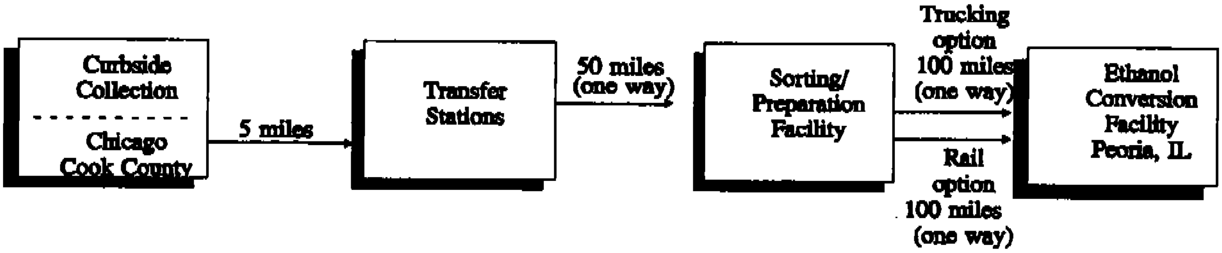
B.1.1.4 Other Considerations

This characterization assumes that recycling already has established end markets and infrastructure. Thus, current and projected recycling efforts (including composting) have been taken out of all waste streams considered. In addition, MSW designated for waste-to-energy facilities has also been deducted from our MSW calculations. Therefore, the pool of waste available for the ethanol plant is equal to the unutilized waste fractions of Chicago's residential and Cook County's residential and commercial wastes less the MSW currently used in Chicago's Northwest Waste-to-Energy facility and the amounts projected for the Robbins facility in Cook County (on line in 1995). (Note: The numbers given above for Chicago and Cook County reflect only the available waste stream.) It should be noted that cellulosic and organic materials from the recycling stream could be a potential feedstock source in the future if the demand for these recyclables remains low.

B.1.2 Logistics

The following flowchart depicts the logistics for the collection, transfer, separation, and transport to the conversion facility.

Transportation Logistics Flowchart



Outlined below is a general description of each major step and the major location and process assumptions. Each step is described in greater detail in Sections B.2 through B.5.

B.1.2.1 Curbside Collection of Mixed MSW

As mentioned earlier, only curbside or at-site collection of mixed MSW is considered. This excludes all materials that are separated at the curbside as part of recycling efforts or programs for both Chicago and Cook County. Additionally, bulky materials from residential wastes such as laundry washers and dryers, and refrigerators are assumed to be collected by special purpose collection vehicles and are subtracted from our estimates of the residential waste stream. As will be discussed in detail in Section B.2, estimates have been made on the percentage of mixed MSW collected from Chicago and Cook County.

B.1.2.2 Range, Routes

B.1.2.2.1 Collection Vehicles

Average distance for a waste collection vehicle for Chicago in 1991 was estimated at 4 miles per trip.[5] Data estimating the average distance for curbside collection in Cook County have not been estimated by county officials. However, Cook County currently has nine transfer stations within its border for curbside collection vehicles to unload MSW. Cook County also has a less dense average of population per square mile than Chicago since all areas of the county are not highly urban. Therefore, we have assumed the average distance to a transfer station for the combined area of Chicago and Cook County will be 5 miles per collection vehicle trip. This distance will be used in transportation calculations and location assumptions of transfer stations for 1990 and 2000.

B.1.2.2.2 Transfer and Long-Haul Vehicles (Between Transfer Station and Sorting/ Preparation Facility)

Tractor-trailer vehicles are assumed to haul the requisite MSW the 50 miles to the sorting/ preparation facility, due to the longer distances involved and lesser load capacity of refuse collection vehicles. The economic rationale behind this assumption and the use of transfer stations is discussed below.

B.1.2.3 Transfer Stations

B.1.2.3.1 Location

Currently, the location of MSW service sites are numerous throughout Chicago, Cook County and surrounding areas (Figures B-1, B-3, B-4). Some of these locations provide MSW services such as landfilling, landfilling/transfer station, transfer station, and waste to energy facilities. By the year 2000, several of these locations are projected to be closed, which would increase the distance for final MSW disposal. This suggests that the distance traveled by long-haul vehicles in the two areas would also increase (Figure B-5). However, our characterization assumes that to manage the waste streams, current landfill locations which will be closed by the year 2000 will be modified to become transfer stations that will move the MSW further into rural areas. This assumption is supported because it is not economical to allow relatively low volume collection vehicles to travel long distances. Figure B-6 illustrates the economics of different types of MSW vehicles over varying hauling distances. The estimated costs for a ton-mile are only used as a scenario to justify the rationale for using transfer stations for shipping MSW over long distances.

Additionally, not placing transfer stations at existing sites would require extensive reorganization of collection routes, purchases of new land to site new transfer facilities and new permits. Projected waste reduction measures in both areas will not diminish the need for transfer stations to prepare MSW for long distance hauling in the future.

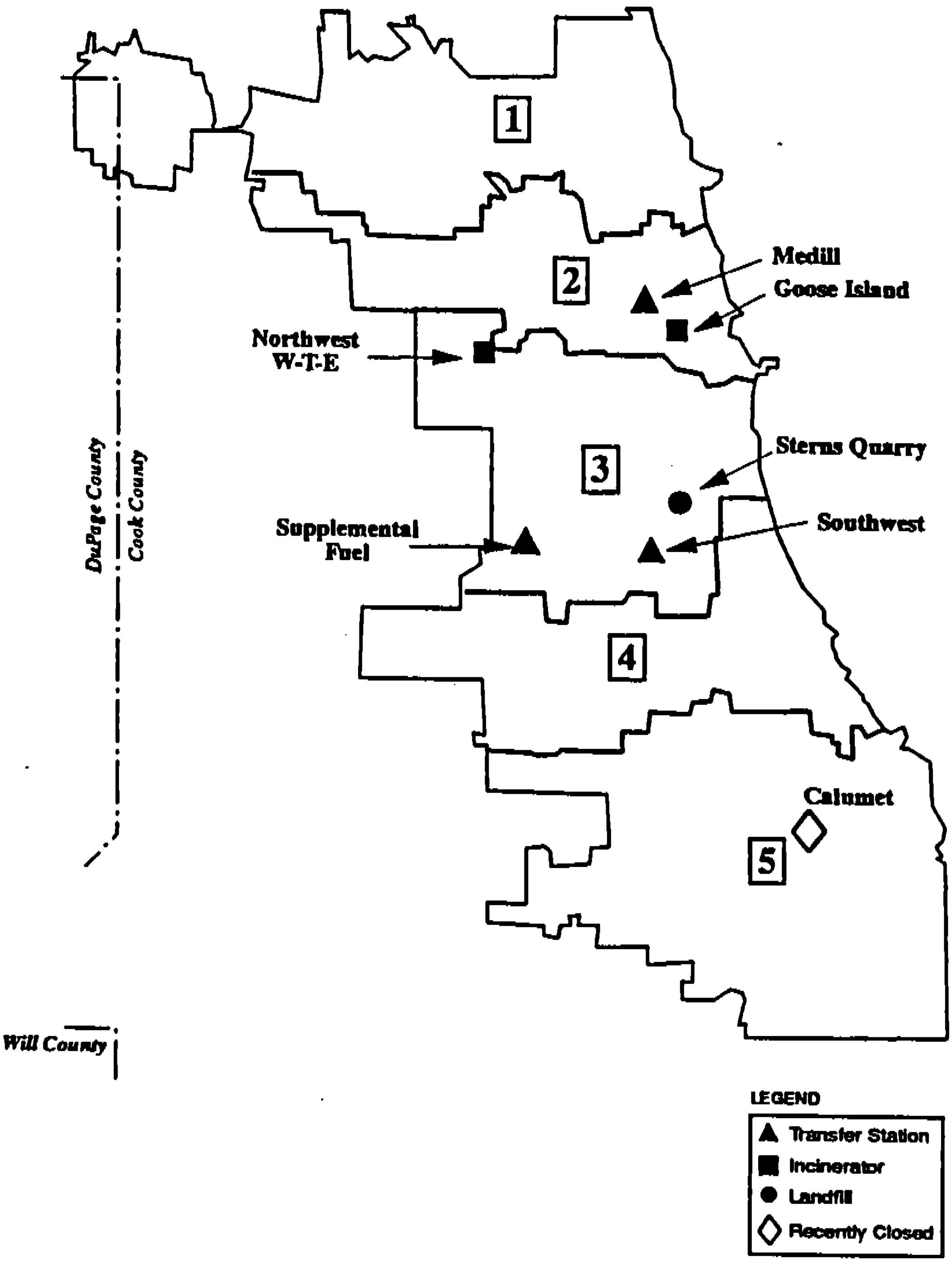
B.1.2.3.2 Transfer Station Types

Currently there exists a wide range of transfer station configurations used in the MSW industry. Each of these configurations has advantages and disadvantages, as outlined in Table B-1. New transfer facilities are assumed to be built based on a hydraulic compactor-hydraulic push pit design. This design was selected because large volumes per day are required to be transported via truck approximately 50 miles to a sorting/preparation facility, and bulky wastes will be pre-sorted from the residential and commercial (Cook County only) wastes, the facility configuration chosen here for Chicago and Cook County can use (and therefore is included for the characterization) a hydraulic compactor-hydraulic push pit design for the new transfer facilities. Five hydraulic compactors will be needed to move the required 3800 tons of raw MSW within a 9 hour/day, 7 day week operation cycle assuming compactor capacities of 100 to 120 tons/hour.

B.1.2.4 Sorting/Preparation Facility

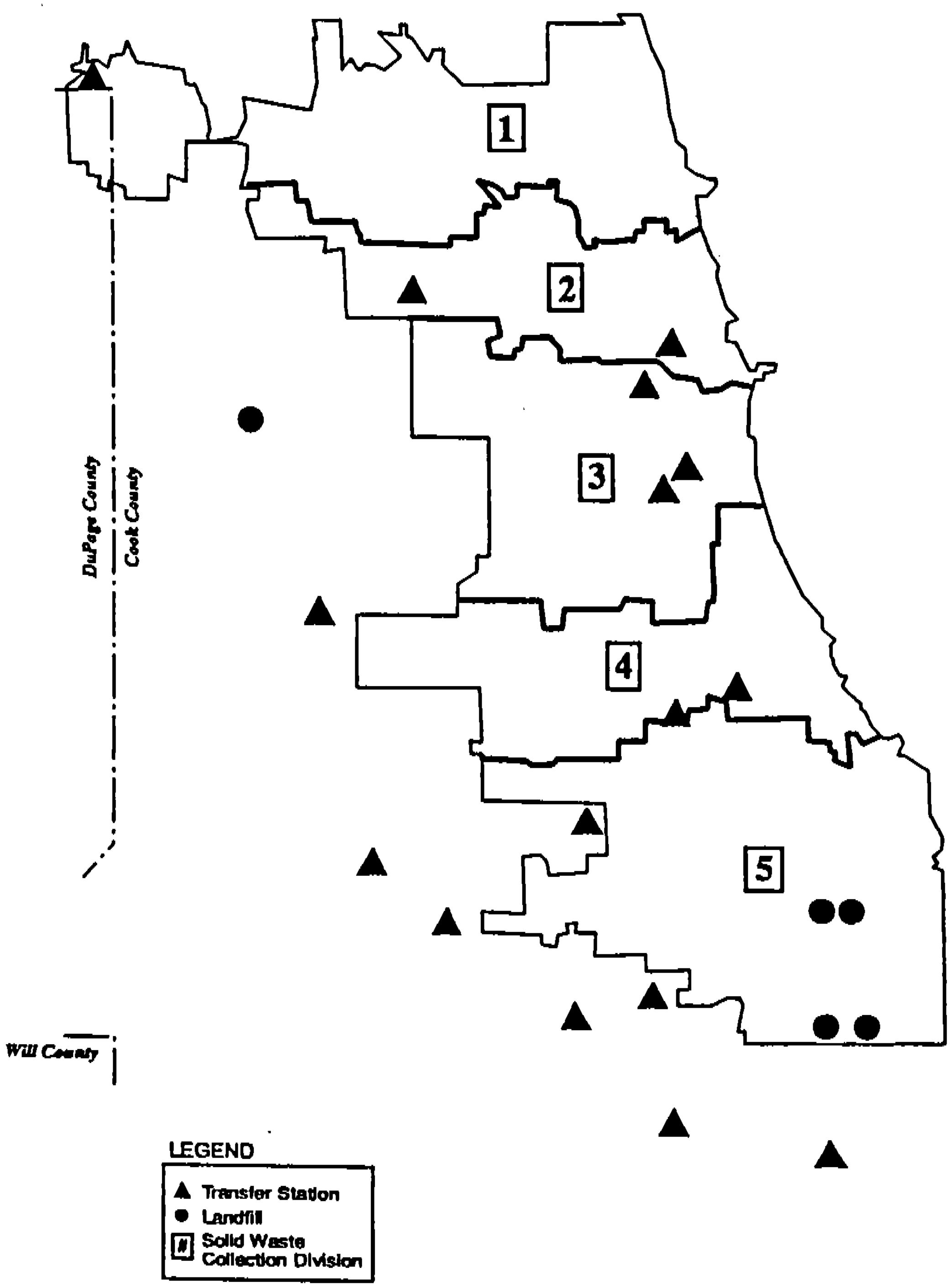
B.1.2.4.1 Technology and Feedstock

MSW sorting/preparation technologies are used in current industry for energy recovery, through either combustion or recycling. Table B-2 discusses the advantages and disadvantages associated



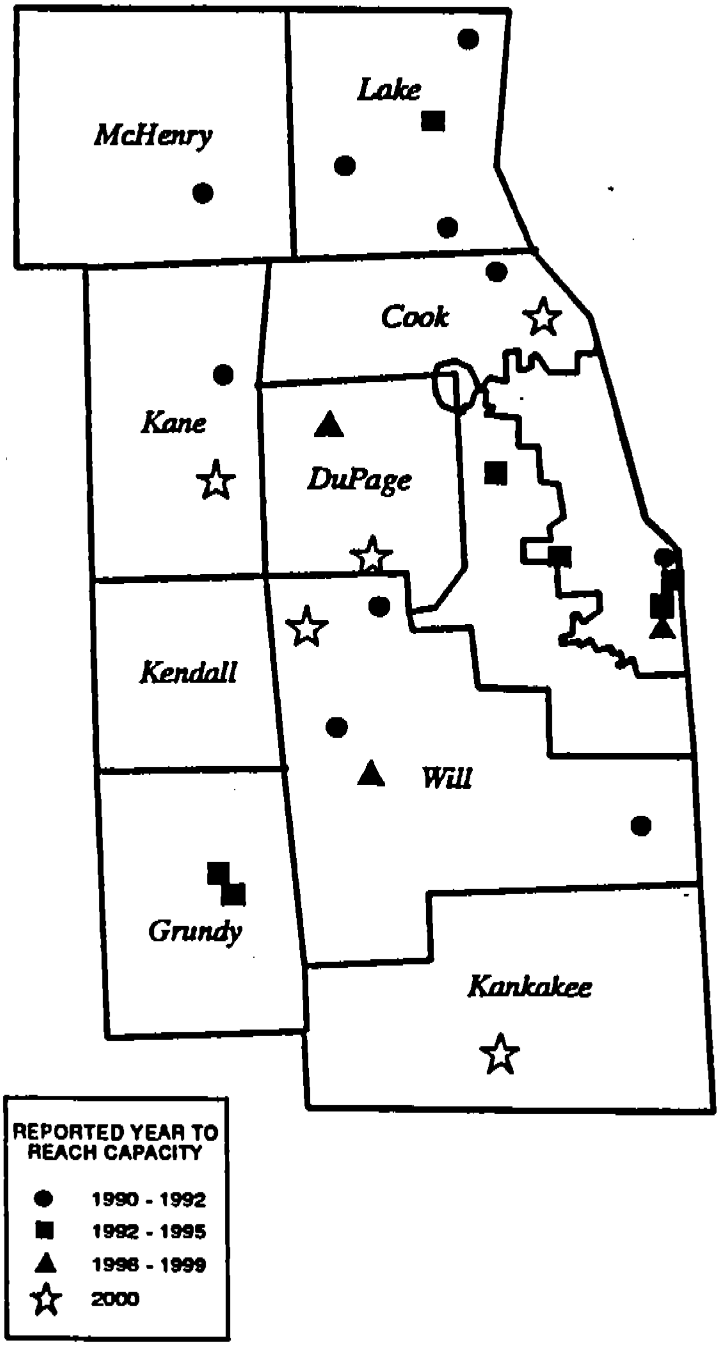
Source: HDR Engineering, Inc., Solid Waste Management Plan for City of Chicago, Volume II, August 23, 1991. pp. 2-4.

Figure B-3. City of Chicago's Publicly Owned Municipal Disposal Facilities



Source: HDR Engineering, Inc., Solid Waste Management Plan for City of Chicago, Volume II, August 23, 1991, pp. 2-6.

Figure B-4. City of Chicago Privately Operated Solid Waste Facilities



Source: Illinois Environmental Protection Agency, Available Disposal Capacity for Solid Waste in Illinois, Fourth Annual Report, October 1990. p. 34.

Figure B-5. Region 2 - 1990 Active Non-Hazardous Landfills Subject to State Fee

with these processes. These current processes do not sort/separate/recover the MSW to the levels required for a biomass-to-ethanol facility (B.1.1.1). Furthermore, current processes, as noted above, depend heavily on some fractions of the waste stream (i.e., separated paper/paperboard for recycling, mixed paper for refuse derived fuel, or aluminum for cans). Since both waste-to-energy processes and recycling rely on the cellulosic fraction, we could not use existing facilities. Therefore, a new dedicated process and facility have been assumed for this MSW to ethanol total energy cycle analysis (see Section B.4).

Additionally, three hydraulic compactor-hydraulic push pits will be required to compress cellulosic/organic material for transport.[4]

B.1.2.4.2 Location

The sorting/preparation facility for our technology characterization is assumed to be sited an average of 50 miles from MSW transfer stations and 40 miles from Chicago. The rationale behind this assumption is that 50 miles is the distance MSW is currently transported for landfills. As landfills close, MSW would have to be shipped even farther than 50 miles. A sorting/preparation facility, such as the one characterized here, located 40 miles from Chicago, will offer an economic alternative to hauling beyond 50 miles in the year 2000. Depending on the method assumed for transportation of feedstock to the ethanol conversion facility, a sorting/preparation would have to be sited on a major highway or railway between Chicago and Peoria.

At the other extreme, for mixed MSW coming from Chicago, it would be economically prohibitive to locate the sorting/preparation facility next to the ethanol production plant in Peoria. If this were the case, one would wind up shipping unwanted fractions of MSW long distances thereby increasing trucking, fuel, labor, and emission expenses. Additionally, other fractions recovered (such as aluminum and ferrous and non-ferrous materials) would have to be shipped back to Chicago for recycling. While the MSW-by-rail option (discussed below) may make the economics not as important a factor, hauling mixed MSW to Peoria and sorted recycables back to Chicago is less efficient, with respect to energy consumption and environmental impact considerations, than siting the sorting/preparation facility near the MSW collection area.

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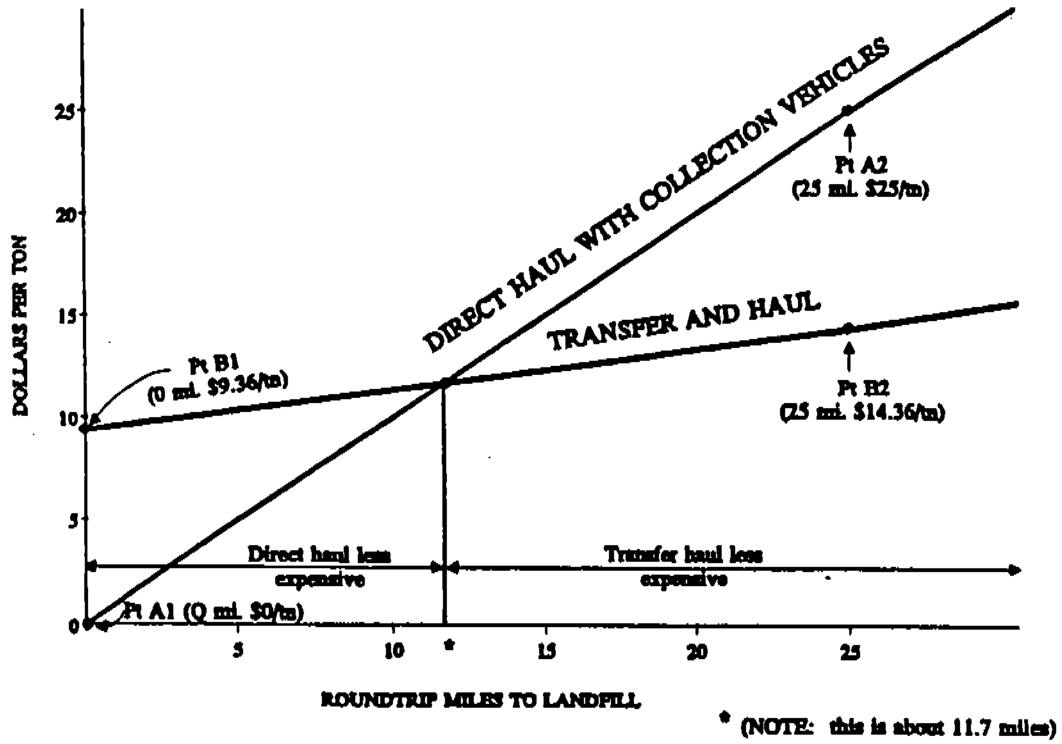
[4] As mentioned earlier, throughput capacity of an industrial compactor is 100-120 tons per hour. Five compactors will compress the needed feedstock for the sorting/preparation facility in the 8 hour workday/ 7-day work-week of tractor-trailer haulers. For the railroad transport option, balers are required which operate at 30-40 tons per hour. However, the rail option assumes railcars will be left at the sorting/preparation facility over a 24 hour period. Therefore, the rail option assumes 24 hour loading and will only require 3 balers.(6)



For Alternative A - haul costs for collection vehicles is given at $1.00 per ton-mile. Thus, at "0" miles, there is no cost (Point A-1) and at 25 miles the cost is $25 (Point A-2). A line is drawn connecting these two points and labeled A - Direct Haul with Collection Vehicles; this line gives the direct haul costs as a function of haul miles.

For Alternative B - the cost of owning and operating the transfer station is $9.36 whether or not the refuse is hauled any distance. Thus, Point B-1 is located at a distance of "0" miles and a cost of $9.36/ton. At 25 miles, the cost is 25 miles at $0.20/mile ($5.00) plus $9.36 for the station for a total of $14.36. This point is labeled B-2. A line is drawn connecting these points and labeled B - Transfer and Haul.

Interpretation: The intersection of the two lines (approximately 12 miles) is the distance at which the costs of direct haul and of transfer are equal; this is the "break-even" point. The graph shows that at distances less than 12 miles the direct haul is the least cost alternative, while at distances greater than 12 miles the transfer system costs less.

Source: Brown, Michael D., et.al., Solid Waste Transfer Fundamentals, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1981. p.4.

Figure B-6. Break Even Analysis - Transfer versus Direct Haul

Table B-1.
Current Industry Transfer Stations

Transfer Station Types	Advantages	Disadvantages
Direct Dump Systems		
Container	• Capital cost is relatively low. • Simple loading method minimizes the possibility of having to halt completely operations due to an equipment breakdown.	• Haul costs are relatively high due to the low densities involved in direct-dump operations. • Provisions for additional dumping locations to accommodate peak periods may be required unless refuse is stockpiled in the unloading area and later pushed into the hoppers with a front-end loader. • Hazards and liabilities are associated with the possibility that someone may fall into a container while unloading refuse. • Leachate may be generated due to rainfall into the open box.

Table B-1.

Current Industry Transfer Stations (Cont'd)

Transfer Station Types	Advantages	Disadvantages
Open-Top Trailer	• Simple loading method. • Open-top trailers are less expensive initially than the alternative compactor-trailer types. • Drive-through provisions for loading transfer vehicles are advantageous and can be incorporated into the design. • This system can handle wastes that are not easily compactible.	• High haul cost because of the low density achieved in direct-dump operations. The use of backhoes to achieve greater density reduces haul costs but increases capital and operating costs of the station. • Hazards and liabilities associated with the possibility that someone may fall into the transfer trailer while unloading refuse. • Low density, or bulky items, are not as easily handled as in a compactor-enclosed trailer system, where compactions can be achieved by hydraulic crushing.
Storage Pit (Crawler Tractor)	• Simple loading method. • Open-top trailers are less expensive in initial cost than the alternative compactor trailer types. • Drive-through provisions for loading transfer vehicles are advantageous and can be incorporated into the design. • The crawler tractor precompacts materials. This allows for more efficient landfill operation. • Storage capability, due to large pit.	• The system must include a leveling operation to distribute the load. • Hazards and liabilities associated with possibility of someone falling into the storage pit while unloading refuse. • Expensive operation and maintenance required on the crawler tractor.

Table B-1.
Current Industry Transfer Stations (Cont'd)

Transfer Station Types	Advantages	Disadvantages
Hydraulic Compaction Systems		
Hydraulic compaction systems in general	• Low transportation costs due to high density achieved through compaction. • The enclosed nature of the trailer or container does not require that trailer tops be handled with each loading and unloading. However, time must be spent coupling and uncoupling the vehicle to the compactor. • The compactor can handle almost any bulky material that can be placed in the hopper.	• Should the compactor fail, there is usually no other way of loading the trailers or containers. • This system requires vehicles to be backed into the station and then attached to the compactor. This prohibits the use of drive-through arrangements. • Not all wastes are compactible with a compaction system; long pieces of steel are normally removed prior to compaction to prevent the steel from puncturing the side of the trailers or containers.
Hydraulic Compaction System Types		
Hydraulic Compactor; Direct to Hopper	• MSW dumped directly into hopper for compaction. No need for front-end loaders. • No storage facility required.	• Since trucks are backed in and MSW is dumped directly; rate of trucks and trash limits this approach to small volume operations.
Hydraulic Compactor; Tipping Floor	• Allows larger volumes of MSW to be processed.	• Requires storage facility (large tipping floor) required for large volumes of trash. • Front-end loaders are required. Expensive maintenance and operation costs are incurred.

Table B-1.

Current Industry Transfer Stations (Cont'd)

Transfer Station Types	Advantages	Disadvantages
Hydraulic Compactor; Incline Conveyor	• Allows larger volumes of MSW to be processed.	• Oversize, bulky wastes sometimes present problems since they can get hung up on conveyors and to bridge at the compactor hopper. • Presorting by front-end loaders may be required. Expensive maintenance and operation costs may be incurred.
Hydraulic Compactor; Hydraulic Push Pit	• Allows the largest volume of the hydraulic compactor techniques to be processes. • Refuse is fed automatically to the compactor by means of a hydraulically-activated ram. • Dumping can be done directly by trucks and/or front-end loaders simultaneously.	• Would require large tipping floors (storage) if front-end loaders are used. • Front-end loaders would require expensive maintenance and operation costs. • Oversize, bulky wastes may bridge over the hopper that feeds the compactor unit. A backhoe may be necessary to push the material through hopper opening. Some presorting of bulky wastes may be required by front-end loader.

NOTE: For all the Hydraulic Compaction Systems, compaction can occur in enclosed trailers or enclosed containers. The enclosed trailer approach is the predominant transfer system used today, and will be assumed in this analysis.

Source: Brown, Michael, D., et. al., Solid Waste Transfer Fundamentals, Ann Arbor Science Publishers Inc. 1981, Ann Arbor, Michigan, pp. 16-22.

Table B-2.
Current Industry Energy Recovery/Sorting Facilities

Energy Recovery/Sorting Systems	Advantages	Disadvantages
Water Well Combustion		
Unprocessed or received ("mass" or "bulk" burning)	• Combusts unprocessed or as-received MSW. • Relatively simple system that can handle large MSW volumes.	• No sorting is used that can help extract cellulosic and organic fractions of MSW. • No sorting of MSW before burning can increase air emissions over other methods. • High residual ash content (volume).
Shredded Wastes	• Shredding waste before combustion produces a more homogenous and controllable fuel. • Equipment such as shredders and trommels are useful to reduce size of material (required for Ethanol Conversion Facility) and low level sorting.	• Still does not allow refined extraction of cellulosic and organic materials. • Lower ash content (volume) than the unprocessed method. • Slightly lower air emissions.

Table B-2.

Current Industry Energy Recovery/Sorting Facilities (Cont'd)

Energy Recovery/Sorting Systems	Advantages	Disadvantages
Refuse-Derived Fuel (RDF)	• Shreds wastes, sorts MSW into a light combustible fraction called RDF. • Greatly reduces ash content. • Some RDF facilities sort out other waste streams such as ferrous metals, nonferrous metals, and organic materials for composting.	• System relies on light-fraction (mostly paper and plastic) for fuel to run facility and produce steam and/or electricity. • Does not separate the plastic waste stream from the cellulosic fraction which is required by the Ethanol Conversion Facility. • Organic separation is not pure since dirt and other materials are allowable for composting. Further sorting is required for the Ethanol Conversion Facility if the organic fraction is to be recovered. • Lower air emissions due to level of MSW separation.
MSW Recycling/ Sorting Systems	• Usually sorts paper, some plastics, ferrous metals, nonferrous metals, and glass products from the rest of the MSW waste stream. • No incinerator air emissions since sorted MSW material is not used for combustion.	• Does not sort out organic fraction. • Current recycling volumes are not large enough to depend on for an ethanol conversion facility. • Competing for biomass feedstock in an established infrastructure and end product markets.

NOTE: 1) Curbside recycling was not assumed in this MSW Total Energy Cycle Analysis.

2) A complete assessment of the advantages/disadvantages of these technology choices requires Total Energy Cycle Analyses for each technology.

Source: Brown, Michael D., et. al., Solid Waste Transfer Fundamentals, Ann Arbor Science Publishers Inc., Ann Arbor, Michigan, 1981, pp. 37-40.

B.1.2.5 Transport Between Sorting/Preparation and Conversion Facilities

The distance from the sorting/preparation facility to the conversion plant in Peoria, Illinois, is 100 miles. Two transportation options are presented: (1) tractor-trailer option and (2) railroad option. Energy flows are addressed in Section B.5. Emissions analyses are presented in Section B.9.

B.1.2.6 Alternative to Siting of Conversion Facility

During this technology characterization, several factors have surfaced that point towards locating MSW-to-ethanol conversion facilities on the outskirts of major urban centers. First, the feedstock (MSW) is there and will continue to be there, in light of landfill closings. Second, the end-use market for the ethanol is, and will be, in major urban centers. This factor is accentuated by the requirements of the Clean Air Act Amendments of 1990 and the potential of additional cities opting into the California low vehicular emissions program. The markets for recycled materials (such as metals, glass, and paper products) are also located in major urban centers. An integrated facility that would take a "free" feedstock (MSW) and convert it to ethanol, steam/electricity, and recyclable goods, with minimum transportation costs should do very well economically. At the same time, this integrated facility would avoid the economic and social costs associated with landfills.

B.1.3 Inputs

B.1.3.1 Land

B.1.3.1.1 Transfer Stations

The same amount of land will be required as is already being used for MSW collection in Chicago and Cook County.

B.1.3.1.2 Sorting/Preparation Facility

Siting a new facility will be required. Acreage requirements can vary for a sorting/preparation facility from 0.5 to 15 acres.[7] Land requirements were taken from estimates for waste to energy facilities. The range was based on tonnage, required traffic, and whether the facility has any or all of the following: resource recovery, administration buildings, and a vehicle corporation yard. Since this sorting/preparation facility will require a large amount of MSW feedstock and traffic, 12 acres will be assumed.

B.1.3.2 Equipment

B.1.3.2.1 Transfer Stations

Transfer stations require the following types of equipment:

- Processing Equipment
- Handling Equipment
  - 5 Hydraulic Compactors
- Off-Highway Vehicles
  - 5 Wheel Loaders
  - 5 Integrated Tool Carriers

B.1.3.2.2 Sorting/Preparation Facility

- Processing Equipment (see Section B.4 for greater detail)
- Handling Equipment
  - 5 Hydraulic Compactors (trucking option only)
  - 3 Balers (rail option only)
- Off-Highway Vehicles
  - 2 Wheel Loaders (both transport options)
  - 2 Integrated Tool Carriers (trucking option only)
  - 5 Integrated Tool Carriers (rail option only)

For greater detail see Section B.9.

B.1.3.3 Labor

B.1.3.3.1 Transfer Stations

Labor inputs for transfer stations are estimated[5] to be:

- 3 crews = 4 days/week - 10 hours/day
- 2 crews = 5 days/week - 8 hours/day
- 80 waste haulers
- 58 other transfer station personnel
- 138 total full-time transfer personnel required
- 5,520 total man-hours/week

[5] Estimates of number of shifts, labor categories, and man-hours are based on an analysis of the Fairfax I-66 Transfer Station in Fairfax, Virginia. The shifts are staggered to account for peak operating hours. This station handles 1,777 tons/day of MSW. For our characterization, it is assumed that double the amount of employees would be required to transfer the 3,800 tons required in 2000.(8)

B.1.3.3.2 Sorting/Preparation Facility

At the sorting/preparation facility, it is estimated[6] that 135 employees, accounting for 5,400 man-hours/week (3 shifts, 24 hours/day), will be required.

B.1.3.4 Energy

B.1.3.4.1 Electricity

Electricity required for transfer stations and a sorting/preparation facility is assumed to be representative of the electric fuel mixture for the state which in 1989 was 59.0% nuclear, 40.3% coal, 0.4% gas, 0.3% fuel oil and minimal hydro.[10]

Electricity requirements for hydraulic compactors used at transfer stations and a sorting/preparation facility are estimated (based on a 250 hp engine) to be 1.41 kWh per ton, assuming a compacting rate of 100 tons/hr.[11] Balers used in this analysis for the rail option, are assumed to have a power rating of 200 hp, compacting 30-40 tons/hr. This rate of compaction equates to 3.76 kWh per ton. All other electricity consumption figures are dealt with in Section B.4.[7]

B.1.3.4.2 Diesel Fuel

Diesel is the fuel assumed to be used for front end loaders and integrated tool carriers at transfer stations and sorting/preparation facility. The energy requirements and emissions associated with these vehicles are discussed in Section B.9.

B.2 MSW Composition

B.2.1 Assumptions and Rationale

B.2.1.1 Chicago MSW

The Draft "Solid Waste Management Plan" for the City of Chicago (see Reference 1) was consulted to determine the MSW generation and composition for 1990 and 2000. MSW composition data were only given for the residential stream, which comprises 42% of the total waste stream. Due to the lack of high quality data on the composition of the commercial and industrial waste streams (50% of total MSW), only the residential waste stream for Chicago is included in our calculations.

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6 Estimates are based on plans for the Robbins Waste-to-Energy facility, designed to handle 1,360 tons/day of MSW and employing 85-95 people.(9)

7 Some nominal amounts of electricity will be required for heating and lighting of transfer stations and sorting/preparation facility. This amount of electricity has not been included in this analysis.

B.2.1.1 Recycling

MSW calculations for 1990 and 2000 do not include recycled materials (including composting). The Chicago "Solid Waste Management Plan" provides the composition of MSW minus current recycling rates for each component of the waste stream. Expected recycling rates for 2000 were not included. Therefore, amounts of MSW to be recycled were calculated using the recycling projections for Cook County (see Reference 4). A statewide mandate for 25% recycling by 1995, will probably lead to uniform increases in recycling statewide, making this a sound assumption.

B.2.1.1.2 Bulky Waste

Bulky waste is assumed not to enter the "normal" waste stream since it is sorted at the curbside and thus is not included in our residential MSW calculations. The MSW composition data from Chicago were recalculated to account for this.

B.2.1.1.3 Northwest Waste-To-Energy-Facility

The Northwest Waste-to-Energy Facility presently consumes an average of about 1,200 tons per day of the city's residential waste. In order to not compete or interfere with current or future operations, this amount of MSW (1,200 tons per day) was also subtracted from the total MSW stream calculations.

B.2.1.2 Cook County MSW

The amount of residential MSW generated in the City of Chicago (given the recycling, bulky waste, and Northwest facility assumptions) is not enough to support the proposed waste-to-ethanol facility. Data from Cook County has been included to provide enough MSW feedstock for the proposed facility. The "Solid Waste Needs Assessment" (see Reference 4) for Cook County was referenced to determine the MSW generation and composition for 1990 and 2000. Unlike Chicago, the commercial/industrial waste stream has been included as well as the residential waste. It should be noted that Cook County based its MSW composition calculations and future projections on national averages provided in the U.S. EPA report, "Characterization of Municipal Solid Waste in the United States,"[12] a widely referenced document for such studies. No additional analyses were performed for Cook County MSW.

Cook County developed several scenarios of future projections based on varying waste generation and recycling rates. A conservative scenario, in terms of waste reduction and recycling goals, was chosen for the purpose of this study. This scenario provides for 25% recycling as mandated by the State of Illinois and modest increases in waste generation. This scenario also follows Chicago's trends in recycling and waste generation.

B.2.1.2.1 Recycling

As in the projections for Chicago, our MSW calculations are for "available" MSW in Cook County, and thus do not include currently or projected recycled materials.

B.2.1.2.2 Bulky Waste

Bulky waste was not included in the Cook County composition data so it was not necessary to recalculate the composition of the MSW as in the case of Chicago.

B.2.1.2.3 Robbins Waste-To-Energy Facility

A Waste-to-Energy Facility in the Village of Robbins has been planned and has received a development permit. This facility, estimated to come on-line by 1995, is expected to consume 1,360 tons per day of the county's MSW. As was done for Chicago, this amount was subtracted from the total MSW calculations for 2000.

B.2.1.2.4 Wood Waste Projections

Cook County includes wood waste in the "other" category, in the presentation of its MSW composition data. In order to determine the amount of wood in the Cook County waste stream, it was assumed that the percentage of wood in the Cook County waste stream is similar to the Chicago waste stream, thus the Chicago data was used for both.

B.2.2 Composition

B.2.2.1 1990 Baseline

Table B-3 depicts the total MSW available from Chicago and Cook County in 1990, as well as the composition of cellulosic and organic materials. In 1990, residential Chicago produced 1.26 million tons of waste, or 3,440 tons/day. Cook County produced 2.37 million tons of waste, or 6,501 tons/day, for the same time period. Together they produced 3.63 million tons, or 9,941 tons/day. Paper products and organic materials comprised 2.44 million tons of this total, or 67% of the total available MSW for these two waste streams.

Table B-3.
Available Municipal Solid Waste Stream
Chicago Area - 1990

Total Stream		
	Million Tons/Year	**Tons/Day**
Residential Chicago	1.26	3,440
Cook County	2.37	6,501
TOTAL[8]	3.63	9,941

Cellulosic and Organic Composition (Million Tons/Year)			
	Chicago	**Cook County**	**Total**
Paper and Paper Products	0.36	0.82	1.18
Yard Waste	0.26	0.45	0.71
Wood	0.06	0.11	0.17
Food Waste	0.18	0.20	0.38
TOTAL	0.86	1.58	2.44

Remaining Components (Million Tons/Year)			
	Chicago	**Cook County**	**Total**
Aluminum	0.01	0.03	0.04
Ferrous Metals	0.04	0.15	0.19
Glass	0.08	0.23	0.31
Plastics	0.13	0.23	0.36
Other	0.15	0.13	0.28
TOTAL	0.41	0.77	1.18

Sources:
- HDR Engineering, Inc., Solid Waste Management Plan for City of Chicago, Volume II, August 23, 1991.
- Northeastern Illinois Planning Commission, Solid Waste Needs Assessment for the Cook County Planning Area, June 1991.

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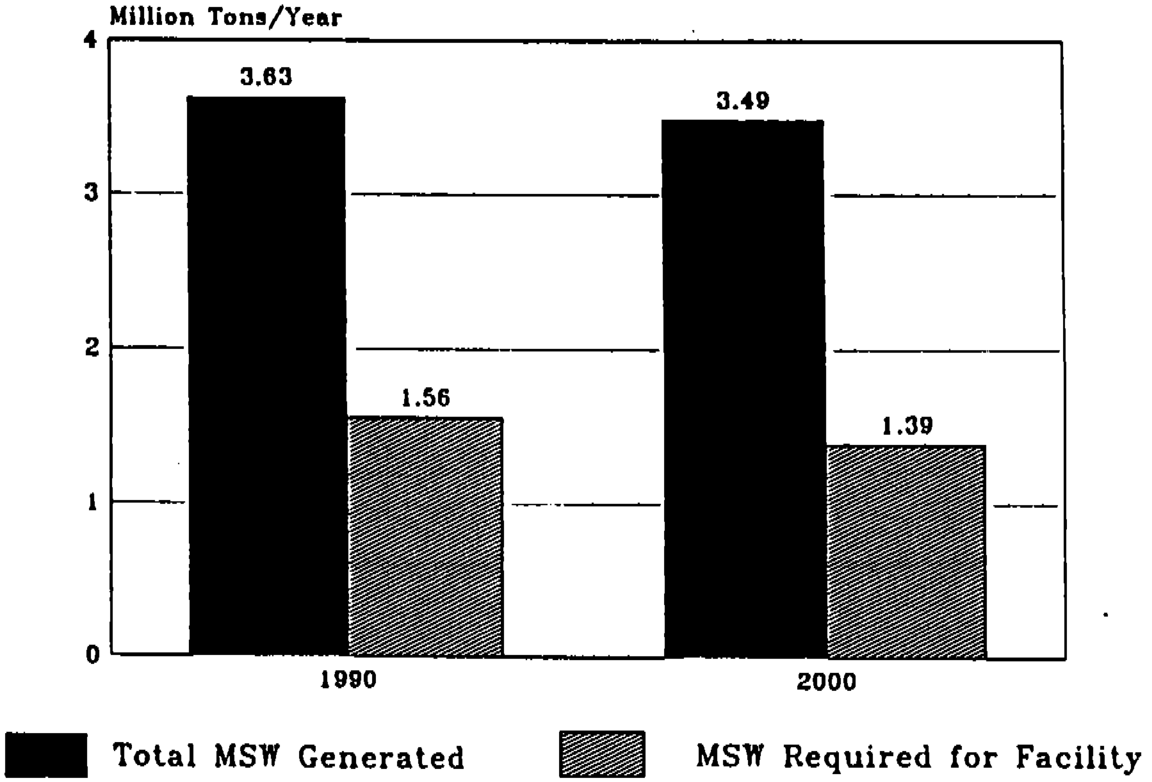
8 Totals below do not add up to 3.63 due to rounding error.

B.2.2.2 Projections for 2000

Table B-4 depicts the available total solid waste stream projections for Chicago and Cook County in 2000. The middle portion of the table shows the expected cellulosic and organic materials composition. Residential Chicago is projected to generate 1.28 million tons of waste, or 3,497 tons/day. Cook County will generate 2.21 million tons of waste, or 6,053 tons/day. Together they will produce 3.49 million tons, or 9,549 tons/day. Paper products and organic materials are expected to comprise 2.36 million tons of this total, or 68% of the total available MSW for these two waste streams. The lower portion of the table shows the composition of the remainder of the waste stream.

B.2.2.3 Required vs. Available Feedstock

Figure B-7 illustrates the total MSW generated in 1990 and 2000 as compared to the feedstock requirements for the sorting/preparation facility.



Note: The amount of raw MSW required for this process decreases in 2000 due to an increase in the organic and cellulosic fraction of the MSW and an estimated increase in the efficiency of the separation technology.

Figure B-7. Total Available MSW (Residential Chicago & Cook County) and Required Raw MSW for Sorting/Preparation Facility - 1990 & 2000

B.2.2.3.1 Feedstock Availability

Between 1990 and 2000, total waste generated for Chicago and Cook County is expected to increase, although not substantially. However, the implementation of a state-wide 25% recycling law will result in less "available" MSW in 2000, as illustrated in Table B-4.

B.2.2.3.2 Feedstock Requirements

The combined waste generated by Chicago and Cook County in 1990 and 2000 would provide more than enough MSW feedstock for a 2,000 dry ton per day waste-to-ethanol facility. The amount of raw MSW required by a sorting/preparation facility in 2000 (in order to yield enough feedstock for the waste-to-ethanol conversion facility) will be 3,800 (wet) tons/day, based on 68% composition of cellulosic (10% water content) and organic (60% water content) materials. See Section B.4 of this appendix for a detailed explanation of feedstock and cellulosic and organic materials requirements.

B.2.2.4 Characteristics of the Cellulose/Organic Fraction (Leaving the Facility)

Table B-5 shows the components of the organic fraction of the material leaving a typical separation facility as feedstock for the waste-to-ethanol facility. The figures represent an estimate of the average composition of the processed organic fraction of MSW, based on composition studies performed by several sources. It should be noted that the "other" category includes plastics. The proposed sorting/preparation facility will be equipped to remove plastics from the material leaving the facility.

Table B-4.
Available Solid Waste Stream Chicago Area - 2000

Total Stream		
	Million Tons/Year	**Tons/Day**
Residential Chicago	1.28	3,496
Cook County	2.21	6,053
TOTAL	3.49	9,549

Cellulosic and Organic Composition (Million Tons/Year)			
	Chicago	**Cook County**	**Total**
Paper and Paper Products	0.42	0.86	1.28
Yard Waste	0.21	0.34	0.55
Wood	0.08	0.13	0.21
Food Waste	0.18	0.18	0.36
TOTAL	0.89	1.50	2.39

Remaining Components (Million Tons/Year)			
	Chicago	**Cook County**	**Total**
Aluminum	0.01	0.02	0.03
Ferrous Metals	0.04	0.02	0.06
Glass	0.08	0.04	0.12
Plastics	0.13	0.30	0.43
Other	0.13	0.33	0.47
TOTAL	0.39	0.71	1.10

Sources:
- HDR Engineering, Inc., Solid Waste Management Plan for City of Chicago, Volume II, August 23, 1991.
- Northeastern Illinois Planning Commission, Solid Waste Needs Assessment for the Cook County Planning Area, June 1991.

Table B-5.
Characteristics of the Cellulose/Organic Fraction
Leaving a Typical MSW Sorting/Preparation Facility
(Weight Percent, Dry Basis)

Components	Percent
Cellulose	45.5
Hemicellulose	8.5
Sugars (and starch) or other carbohydrates	8.5
Protein	3.3
Ash	15.0
Lignin	10.0
Fats and greases	6.7
Other	2.5
TOTAL	100.0

Source: SRI estimates based on composition information from several sources.

B.3 Collection Technologies

B.3.1 Assumptions

For this portion of the analysis, it is assumed that MSW will be collected at curbside via refuse trucks which also compact the wastes. Since the technology for these vehicles has not changed significantly in the past years, it was assumed that this will be the method of MSW collection in the year 2000. This type of truck is available in three main configurations: front loader, rear loader, and side loader. A front loader is driven up to a refuse dumpster or other large container, lifting the unit, emptying its contents into the top of the truck. A rear loader is used in residential areas where sanitation personnel empty individual refuse containers (trash cans) into the rear of the truck. The final type of collection truck, the side loader, is also loaded manually, but from the side of the vehicle. Recent developments in rear- and side-loader collection vehicles have automated loading somewhat. Hydraulic arms are attached to some of these trucks which pick up roll-away refuse containers and empties them into the vehicle.

The most common collection trucks have capacities between 16 and 40 cubic yards (yd^3), with engines ranging from approximately 200 to over 350 horsepower (Hp), and are capable of compaction ratios of between 750 and 900 pounds per cubic yard (lb/yd^3).[13] The average truck was assumed to be similar to a White Expeditor II, having a capacity of 25 yd^3 and a 210 Hp engine.

The fuel used for 1991 is assumed to be diesel, as is currently the case, with a maximum sulfur content of 0.1%. For the year 2000, the fuel is assumed to be a low-sulfur diesel (less than 0.05%) with a minimum cetane rating of 40. There may be a few alternative-fueled trucks, but more than likely, it will be a negligible amount, and therefore is not considered in the analysis. The factors used for the truck emissions, in both 1991 and 2000, are presented in Table B-6.

The pollution control technologies incorporated into the 1991 collection trucks are minimal, and include turbochargers and smoke puff limiters. Turbochargers allow the fuel and air to better mix in the combustion chambers, while smoke-puff limiters control emissions by limiting the amount of fuel flow into the cylinders upon acceleration until the turbocharger is up to speed. For the year 2000, diesel particulate traps may appear on some models, possibly in conjunction with catalytic converters.

The average speed of the collection trucks is assumed to be approximately 5 miles/hour. This is a conservative figure, but it takes into account the great number of stops these vehicles make and the long periods of idling at those stops and during compaction.

Table B-6.
Heavy Duty High Speed Diesel Engine Emissions
(gm/bhp-hr)

Year	HC	CO	NO_x	PM	SO_x	CO_2	VOC	Aldehydes
1990	1.1	4.8	4.8	0.5	0.2	724.0	NIL	NIL
2000	1.0	3.0	3.8	0.1	0.2	666.1	NIL	NIL

B.3.2 Collection Parameters

B.3.2.1 Current Baseline (1990)

The amount of MSW collection required to support the MSW-to-ethanol facility under ideal conditions (i.e., no losses) was determined to be 4,270 tons/day (see Section B.4). Assuming an average loss during transit and handling of 20 lb/ton, the total loss is obtained by multiplying 4,270 by 20 lb/ton to arrive at 85,400 lb/day or 42.7 ton/day. Adding 4,270 ton/day to 42.7 ton/day gives approximately 4,315 tons/day of unseparated or mixed MSW that actually needs to be collected at curbside. (The reader is reminded at this juncture that MSW collected at curbside has yet to be transferred, sorted, separated, and transported before arriving at the ethanol production facility. All of these steps reduce the tonnage to approximately 2,500 tons/day).

To determine the number of trips required for the collection trucks, the total MSW to be collected (4,315 tons/day) was divided by the average amount of MSW hauled per load, 3.5 tons,[14] which yields 1,233 trips/day. To arrive at the number of collection trucks required for this amount of MSW, the average number of trips/day was divided by 2.5, the average number of trips/truck,[15] to get 494 trucks required. An average hauling distance of 5.0 miles (see Section B.1) and the emission factors presented in Table B-6 will be used in the emissions/analysis portion of this study.

B.3.2.2 The Year 2000 Time Period

As above, the actual amount of MSW needed was determined by adding the total amount of MSW required, 3,800 tons/day (from Section B.4), to the average loss in transit and handling of 20 lb/ton to arrive at 3,840 tons/day of MSW to be collected. The number of trips required for the collection trucks is the total MSW to be collected (3,840 tons/day) divided by the average amount of MSW hauled per load, 3.5 tons. This figure is 1,098 trips/day. The number of collection trucks required for this amount of MSW is the number of trips/day divided by the average number of trips/truck, 2.5, yielding 440 trucks that are required. An average hauling distance of 5.0 miles (see Section B.1) and the emission factors presented in Table B-6 will be used in the emissions/analysis part of this study.

B.3.3 Inputs

B.3.3.1 Current Baseline (1990)

B.3.3.1.1 Energy

To obtain the amount of fuel used in each collection truck per day of operation, it was assumed that each truck used an average of 3.0 gallons/mile when the amount of idling, loading, and compacting is considered. Multiplying 3.0 gal/mi by the 5.0 average trip distance (see Section B.1), and by the average of 2.5 trips/day per truck, gives an average of 37.5 gallons of diesel fuel a day per truck.

B.3.3.1.2 Labor

If the number of workers per collection truck is assumed to be 3 (1 driver and 2 laborers), the total number of workers required to operate these trucks was obtained by multiplying 3 by 494 trucks (the number of trucks required from above) gives 1,482 workers staffing the trucks. More employees will be required, however, to handle the workload as the 1,482 workers take sick leave and vacation time.

B.3.3.2 The Year 2000 Time Frame

B.3.3.2.1 Energy

To obtain the amount of fuel used in each collection truck per day of operation, it was assumed that each truck used an average of 3.0 gal/mi when the amount of idling, loading, and compacting is considered. Multiplying 3.0 gal/mi by the 5.0 average trip distance (see Section B.1), and by the average of 2.5 trips/day per truck, gives an average of 37.5 gallons of diesel fuel a day per truck.

B.3.3.2.2 Labor

If the number of workers per collection truck is assumed to be 3 (1 driver and 2 laborers),[16] the total number of workers required to operate these trucks can be obtained by multiplying 3 by 440 trucks, giving 1,320 workers staffing the trucks. This is under ideal circumstances and more workers will actually be needed to cover the vacation and sick leave of these employees.

B.4 Sorting/Preparation Technology

B.4.1 Assumptions

B.4.1.1 MSW Feedstock Required

The characteristics and requirements of MSW feedstock for the sorting/preparation facility are given in Table B-7. The organic fraction entering the sorting/preparation facility contains 60% water, while the waste paper fraction contains 10% water. The overall moisture content of the raw MSW feedstock is assumed to be 25%. For the year 1990, the sorting/preparation facility will take in 4,270 tons/day of wet MSW. The facility will yield 2,505 tons/day of wet organic/paper material. This is equivalent to 2,020 dry tons/day, which is sufficient to supply the ethanol conversion facility with its required 2000 dry tons/day. The projections for MSW feedstock required by the year 2000 assume the achievement of significant technology improvements. For the year 2000, the sorting/preparation facility will take in 3800 wet tons/day of MSW and yield 2,505 wet tons/day (which is equivalent to 2,020 dry tons/day) of organic/paper material.

B.4.1.2 Particle Size and Energy Requirements

B.4.1.2.1 Primary Shredder

Before shredding, it is assumed that some coarse and larger bulk items such as tires, have been previously removed to avoid stalling or jamming of the shredders. This could be achieved either by a trommeling or a manual sorting at the transfer station.

The primary shredder is assumed to reduce the size of MSW to 3 inches. The energy required to achieve this is 5 kWh/ton of raw MSW.

B.4.1.2.2 Secondary Shredder

Energy requirements for reducing the particle size have been shown to increase sharply as increasingly small particle sizes are produced. The secondary shredder is designed to reduce the size to 1 inch. This is the required size for the biomass fraction of MSW to be sent to the ethanol conversion facility. The energy required is 13.6 kWh/ton.

B.4.2 Process Flow

B.4.2.1 System Design

Currently, most existing MSW conversion plants produce a refuse derived fuel (RDF) to be used as a feedstock to power electricity generation facilities. One MSW plant is reported to produce RDF for anaerobic digestion. But, to the best of our knowledge, no commercial facility exists

Table B-7.
Characteristics of MSW Feedstock for the Sorting and Preparation Facility
(Wet Basis)

Year 1990							
Component	Moisture Content	MSW (mf)	MSW (tpd)	MSW Composition (mf)			
				Solid		Water	
				tpd	mf	tpd	mf
Paper	0.10	0.330	1,408.70	1,267.83	0.30	140.87	0.03
Organics	0.60	0.342	1,459.93	583.97	0.14	875.96	0.21
Plastics	0.08	0.100	426.8	392.73	0.09	34.15	0.01
Fe	0.05	0.053	226.25	214.93	0.05	11.31	0.00
Al	0.05	0.011	46.96	44.61	0.01	2.35	0.00
Glass	0.05	0.085	362.85	344.70	0.08	18.14	0.00
Other	0.06	0.079	337.23	317.00	0.07	20.23	0.00
Totals		1.000	4,268.79	3,165.77	0.74	1103.0	0.26
Year 2000							
Component	Moisture Content	MSW (mf)	MSW (tpd)	MSW Composition (mf)			
				Solid		Water	
				tpd	mf	tpd	mf
Paper	0.10	0.365	1,387.00	1,248.30	0.33	138.70	0.04
Organics	0.60	0.321	1,220.00	488.00	0.13	732.00	0.19
Plastics	0.08	0.120	456.00	419.52	0.11	36.48	0.01
Fe	0.05	0.016	61.00	57.95	0.02	3.05	0.00
Al	0.05	0.008	30.00	28.50	0.01	1.50	0.00
Glass	0.05	0.035	133.00	126.35	0.03	6.65	0.00
Other	0.06	0.135	513.00	482.22	0.13	30.78	0.01
Totals		1.000	3,800.00	2,850.84	0.75	949.16	0.25

mf = mass fraction
tpd = tons per day
Fe = ferrous metals
Al = aluminum

which extracts the organic fraction from MSW to produce ethanol. This effort collected information representing today's technology with regard to MSW collection, sorting and preparation projections for the 2000 time frame. The available information was used to design this MSW sorting and preparation facility.

B.4.2.2 Process Equipment

The process flow for the sorting/preparation stage is shown in Figure B-8. The main stages include the transfer station, scales, storage, loaders, conveyors, shredders, air classifiers, magnetic separator, trommel screens, cyclones, organic removal jig, and high-tension separator. Raw MSW is loaded onto the conveyor that feeds the primary shredder. The shredded material is conveyed to the light air classifier where the very lightest pieces are entrained through a cyclone. Most of the light-gauge iron is then removed from the shredded MSW by a suspended-belt magnetic separator. The remaining material enters a horizontal primary air classifier from an opening in the top at one end of the classifier and falls into a stream of air, blown horizontally into the side at the same end. Very heavy objects fall vertically through the stream of air to a conveyor which carries them to a container. The light shredded material is entrained through a cyclone where the solids are collected. The intermediate fraction, mostly composed of the glass, aluminum, food wastes, leather, heavy plastics, wood, rubber, and partially shredded heavier-gauge paper and paperboard is conveyed to a rotating trommel screen (2-1/4 inch holes). Glass, food wastes, and small amounts of other organics pass through the 2-1/4 inch holes. Water elutriation of this product in the organic removal jig produces a glass product and an organic waste containing dirt and fine glass. The materials discharged from the end of the trommel are joined with light materials collected by the cyclones, before moving to a secondary shredder. The shredded product discharges directly into a secondary air classifier. The light material is entrained into a cyclone. The heavy material including aluminum, wood, heavy plastic, leather, and rubber falls into a jig where water elutriation separates the organic fraction from aluminum. The final shredded light materials are discharged from the cyclone to an electrostatic separator, where paper and plastics are separated. The description of the main equipment is given below.

B.4.2.2.1 Shredders

Size reduction is usually the first step in a MSW sorting/preparation facility. Two types of shredders are required in this process:

- The primary shredder reduces bulk density, opens bags, and improves the efficiency of subsequent size separation systems.

- The secondary shredder is for size control and improvement of material handling.

Several types of shredders exist, which include hammermills (vertical or horizontal), grinders (roller or disc-mill), ball mill, knife mill, flail mill, etc.

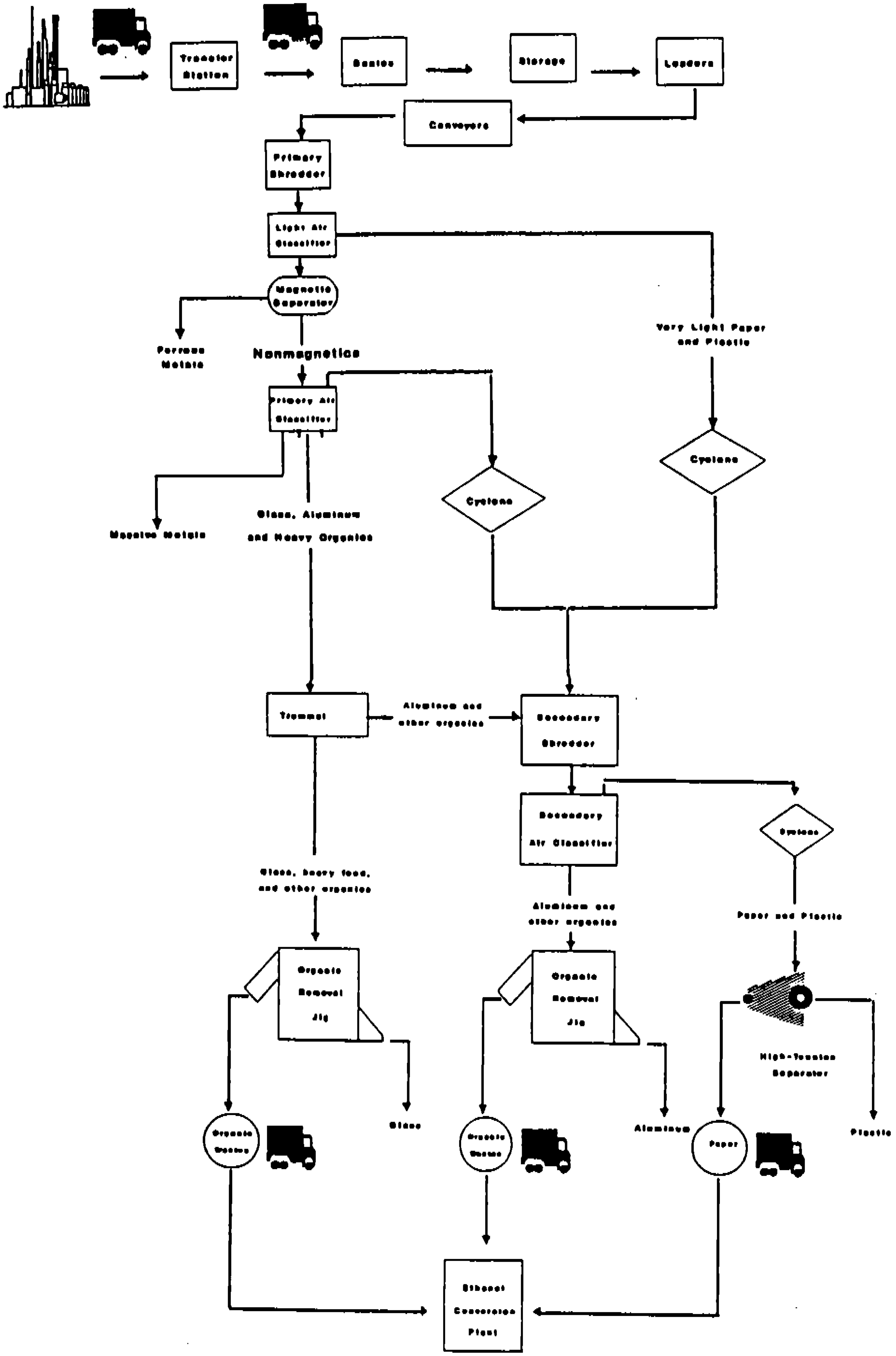


Figure B-8. Waste Collection, Sorting/Preparation: Process Flowchart

B.4.2.2.2 Air-Classifiers

Air classifiers are used to separate shredded waste into fractions based on differences in the density, size and shape of the particle. The shredded waste is introduced into an air-stream. The lightweight material, mostly composed of paper, plastics, and cardboard, is carried in the air stream while heavier materials drop out. Those heavy materials consist of rubber, wood, glass, dirt, rock, metals, and other miscellaneous materials. There are many types of air classifiers. This effort has designed three air classifiers: the light air classifier, the primary air classifier and the secondary air classifier.

B.4.2.2.3 Cyclones

Cyclones are used to recover the solid particles carried by the air stream from air classifiers. This is necessary for two reasons: to recover as much as possible of paper and cardboard particles, which are needed for ethanol production, and to reduce air pollution by recovering most of the solid particles which, otherwise, would be discharged into the atmosphere.

B.4.2.2.4 Trommels

A trommel is a large cylindrical screen that rotates around an axis. The axis is placed at a slight incline to influence movement of the waste through the unit. This rotating cylinder is perforated to allow materials of certain sizes to pass through them. The screening is the separation of a mixture of various sizes of grains into two or more portions by means of a screening surface; the screening surface acts as a multiple go-no-go gauge and the final portions consist of grains of more uniform size than those of the original mixture. Material that remains on a given screening surface is the oversize or plus material, while the material passing through the screening surface is the undersize or minus materials. The material passing one screening surface and retained on a subsequent surface is the intermediate material. Following air classification and shredding, trommels are used on the light fraction to remove dust, grit, and glass particles. They can also be used as processing steps for the recovery of materials in the heavy fraction (e.g., metals and glass).

B.4.2.2.5 Magnetic Separator

Magnetic separators are used to remove magnetic material, primarily ferrous metals, from the mixed MSW. One important reason for removing the ferrous metals is to reduce the amount of ash in the final organic fraction product. A second reason is to recover a saleable product. Furthermore, the removal of the metal reduces wear on subsequent processing and handling equipment.

The magnetic properties of iron and steel make ferrous recovery one of the easiest material separation processes. Magnetic separators work by passing shredded solid waste, carried on a conveyor, past a magnet. The magnets are either suspended over the discharge end of the conveyor or located underneath it. As the wastes pass by the magnet, ferrous metals are picked up and diverted into a separate stream. There are several types of magnetic separators, including drum magnets, single-magnet belts, separators, and multiple magnet-belt-separators. Although magnetic separators are successfully used for numerous industrial applications, their use on MSW presents some unusual problems. The amount of ferrous metals in MSW is relatively high as compared with tramp metal removal requirements from other industrial products. Also, there is a tendency for non-magnetic materials, such as paper and plastics, to be entrapped with the ferrous material, thereby not only reducing the purity of the recovered metal, but also increasing losses of paper/organics needed for ethanol conversion.

B.4.2.2.6 Organic Removal Jig

A jig is a mechanical device used for separating materials of different specific gravities by the pulsation of a stream of liquid flowing through a bed of materials. The liquid pulsates or "jigs" up and down, causing the heavy material to work down to the bottom of the bed and the lighter material to rise to the top. Each product is then drawn off separately. Jigs require much water. In most installations, water requirements are 1,500 to 2,500 gal/ton. However, a portion of this water is usually reused in the jig.

B.4.2.2.7 High-Tension Separator

Electrostatic separation of particles, also commonly known as high-tension separation, is a method of separation based on the differential attraction or repulsion of charged particles under the influence of an electrical field. Applying an electrostatic charge to the particles is a necessary step before particle separation can be accomplished. Various techniques can be used for charging. These include contact electrification, conductive induction, and ion bombardment.

B.4.3 Unit Process Mass Balance Model

A unit process mass balance model is shown in Figure B-9. Each block represents one unit operation or equipment of the process. Letters A, B, ..., N represent a recovery factor transfer function (RFTF) for each unit operation. This factor makes the model more versatile to describe the system mass balance. At the present, this factor can be adequately defined only upon the completion of a detailed analysis and interpretation of data collected from operating facilities. In some instances, recovery factors for certain processes can be calculated from data collected in past and ongoing operations. Through the use of a simple scalar matrix, the component mass inputs (e.g., Fe, Al, glass, paper, organics, etc.) are transformed by way of the RFTF into the outputs for that operation. The intrinsic utility of this modeling approach is in the fact that the RFTF has a physical basis which can be established either through testing or from previously developed analytical expressions. Let us illustrate this concept by applying it to a binary separation device, such as the light air classifier, which divides the input stream matrix X_1, into two output streams matrices X_2 and X_3. By conservation of mass in a binary separator, the recovery factors B and B′ for X_3 and X_2 respectively, are bound to the relationship $B + B' = 1$. Therefore, having established B (by either analytical or testing method), it is easy to calculate B′.

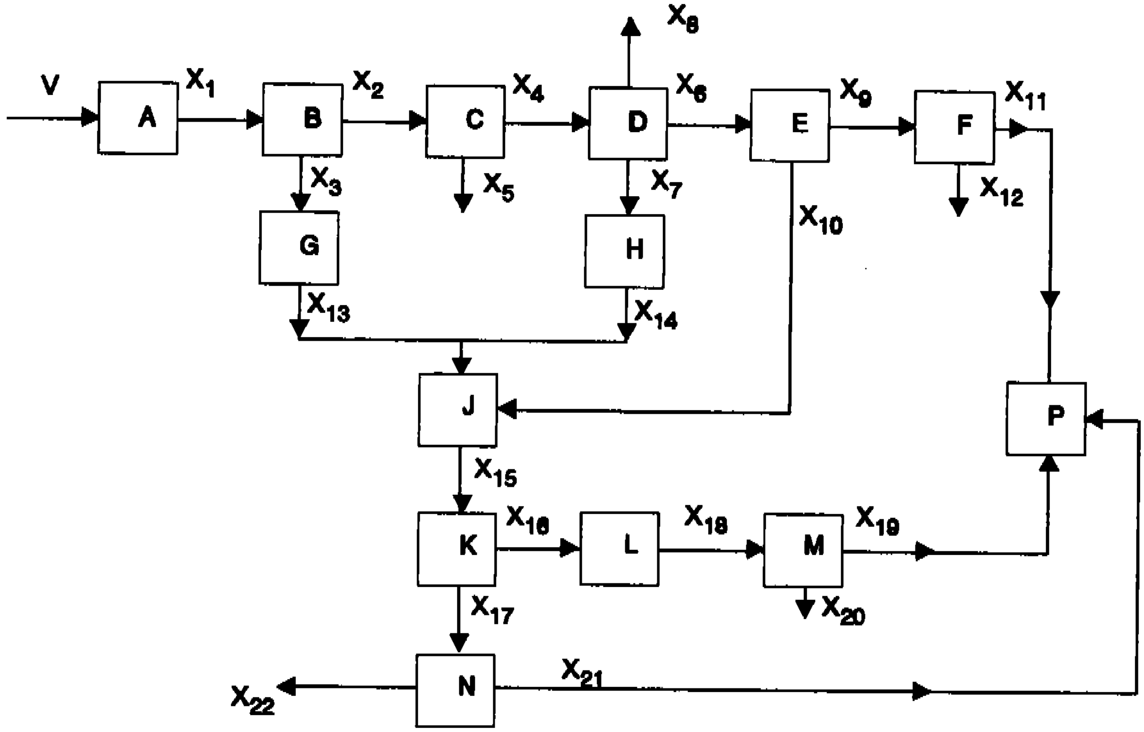


Figure B-9. Unit Process Mass Balance Model for Sorting/Preparation Facility

B.4.4 Material Balance Calculation

The results of the material balance calculation are given in Table B-8. The amount and composition of each stream is shown. The output streams X_{11}, X_{19} and X_{21} represent the recovered product, which consist of paper/organics and amounts to 2505.3 tons/day. The average moisture content of the organics (streams X_{11} and X_{21}) is 34% wt. The moisture content of the recovered paper (stream X_{19}) is 16% wt. The average moisture of the combined paper/organics shipped to the ethanol conversion facility is 19% wt. On a dry basis, the composition of this final product is 82.5% wt of paper/organics and 17.5% wt of ash and others. The detailed composition of the paper/organics is shown in Table B-5. In addition to the recovered 2,020 tons/day (dry basis) of ethanol feedstock, several tons of other valuable materials are also recovered, these including 37 tons/day of ferrous metals (stream X_5). The heating values of each waste stream in the model have also been calculated and are shown in Table B-9. The main input to the facility consists of 1,040,250 dry tons/year of raw MSW, which represents 14,732,000 mmBtu/yr. The facility yields 737,300 dry tons/year of cellulosic material suitable for use as an ethanol feedstock. This cellulosic feedstock is equivalent to 11,626,000 mmBtu/yr. The energy output/input ratio is thus 79%.

Table B-8.
MSW Sorting/Preparation Facility Unit Process Mass Balance *

Component	Raw MSW		A. Primary Shredder	B. Light Air Classifier		C. Magnetic Separator		D. Primary Air Classifier			E. Trommel		F. Organic Removal Jig	
	%	TPD	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Paper	32.8	1,248	1,248	25	1,223	24.9	0.1	0.5	24.4	0	0.1	0.4	0.1	0
Organics	12.8	488	488	146.4	342	146.1	0.3	43.8	102.3	0	32.8	11	32.1	0.7
Water	25.0	950	760	236	524.1	234.5	2.8	111.8	120.7	2	98.7	13.1	40.3	58.4
Plastics	11.0	419.5	419.5	8.4	411.1	8.4	0	0.2	8.2	0	0	0.2	0	0
Fe	1.5	58	58	46.4	11.6	9.3	37.1	7.9	0.9	0.5	1.6	6.3	0.3	1.3
Al	0.8	28.5	28.5	14.3	14.3	14.3	0	7.1	7.2	0	1.4	5.7	0.1	1.3
Glass	3.3	126	126	50.4	75.6	50.4	0	20.2	30.2	0	16.2	4	5.7	10.5
Other	12.7	482	482	313.3	168.7	313.3	0	188	109.7	15.7	141	47	49.4	91.6
Totals	100.0	3,800	3,610	840.2	2,770.4	801.2	40.3	379.5	403.6	18.2	291.8	87.7	128	163.8

Component	G. Cyclone		H. Cyclone		J. Secondary Shredder	K. Secondary Air Classifier		L. Cyclone		M. High-Tension Separator		N. Organic Removal Jig	
	X_{13}	X_{23}	X_{14}	X_{24}	X_{15}	X_{16}	X_{17}	X_{18}	X_{25}	X_{19}	X_{20}	X_{21}	X_{22}
Paper	1,223	0	24.4	0	1,248	1,223	25	1,223	0	1,186.3	36.7	24.5	0.5
Organics	342	0	102.3	0	455.3	319	136.3	319	0	290.3	28.7	133.6	2.7
Water	471.7	52.4	108.6	12.1	521.4	393.8	127.6	354.4	39.4	322.5	31.9	122.2	5.4
Plastics	411.1	0	8.2	0	419.5	411.1	8.5	411.1	0	164.4	246.7	8.4	0.1
Fe	11.6	0	0.9	0	18.8	3.8	15	3.8	0	0.8	3	3	12
Al	14.3	0	7.2	0	27.2	13.6	13.6	13.6	0	1.4	12.2	1.4	12.2
Glass	75.6	0	30.2	0	109.8	65.9	44	65.9	0	23.1	42.8	15.4	28.6
Other	168.7	0	109.7	0	325.4	113.9	211.5	113.9	0	40	74	40	171.5
Totals	2,718	52.4	391.5	12.1	3,125.4	2,544.1	581.5	2,504.7	39.4	2,028.8	476	348.5	233

* NOTE: Fe = ferrous material
Al = aluminum
Xi = Matrix for output stream no. i, consisting of n components, in tons per day (TPD)

Table B-9.
MSW Sorting/Preparation Facility Heating Values of Waste Stream *

Component	Assumed Component Heating Value (Btu/lb)	Raw MSW Btu	A. Primary Shredder	B. Light Air Classifier		C. Magnetic Separator		D. Primary Air Classifier			E. Trommel		F. Organic Removal Jig	
			X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Paper	8,000	$2.0x10^{10}$	$2.0x10^{10}$	$4.0x10^8$	$2.0x10^{10}$	$4.0x10^8$	$1.6x10^6$	$8.0x10^6$	$3.9x10^8$	0	$1.6x10^6$	$6.4x10^6$	$1.6x10^6$	0
Organics	8,000	$7.8x10^9$	$7.8x10^9$	$2.3x10^9$	$5.5x10^9$	$2.3x10^9$	$4.8x10^6$	$7.0x10^8$	$1.6x10^9$	0	$5.3x10^8$	$1.8x10^8$	$5.1x10^8$	$1.1x10^7$
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plastics	15,000	$1.3x10^{10}$	$1.3x10^{10}$	$2.5x10^8$	$1.2x10^{10}$	$2.5x10^8$	0	$6.0x10^6$	$2.5x10^8$	0	0	$6.0x10^6$	0	0
Fe	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glass	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Btu		$4.036x10^{10}$	$4.036x10^{10}$	$3.0x10^9$	$3.8x10^{10}$	$3.0x10^9$	$6.4x10^6$	$7.1x10^8$	$2.2x10^9$	0	$5.3x10^8$	$1.9x10^8$	$5.15x10^8$	$1.1x10^7$

Component	Assumed Component Heating Value (Btu/lb)	G. Cyclone		H. Cyclone		J. Secondary Shredder	K. Secondary Air Classifier		L. Cyclone		M. High-Tension Separator		N. Organic Removal Jig	
		X_{13}	X_{23}	X_{14}	X_{24}	X_{15}	X_{16}	X_{17}	X_{18}	X_{25}	X_{19}	X_{20}	X_{21}	X_{22}
Paper	8,000	$2.0x10^{10}$	0	$3.9x10^8$	0	$2.0x10^{10}$	$2.0x10^{10}$	$4.0x10^8$	$2.0x10^{10}$	0	$1.9x10^{10}$	$5.9x10^8$	$3.9x10^8$	$8.0x10^6$
Organics	8,000	$5.5x10^9$	0	$1.6x10^9$	0	$7.3x10^9$	$5.1x10^9$	$2.2x10^9$	$5.1x10^9$	0	$4.6x10^9$	$4.6x10^8$	$2.1x10^9$	$4.3x10^7$
Water	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plastics	15,000	$1.2x10^{10}$	0	$2.5x10^8$	0	$1.3x10^{10}$	$1.2x10^{10}$	$2.6x10^8$	$1.2x10^{10}$	0	$4.9x10^9$	$7.4x10^9$	$2.5x10^8$	$3.0x10^6$
Fe	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glass	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals		$3.8x10^{10}$	0	$2.2x10^9$	0	$4.0x10^{10}$	$3.7x10^{10}$	$2.9x10^9$	$3.7x10^{10}$	0	$2.85x10^{10}$	$8.5x10^9$	$2.78x10^9$	$5.4x10^7$

* NOTE: Fe = ferrous material
Al = aluminum
Xi = Matrix for output stream no. i, consisting of n components, in pounds per day

B.4.5 Inputs

B.4.5.1 Energy

Table B-10 shows the energy requirement for each equipment, and the total energy needed to run the facility, which amounts to 121,061 kWh/day, or 44,187,265 kWh/yr. This does not include the amount of energy consumed by scales, storage loaders, conveyors and lights. The secondary shredder alone represents 36% of the total energy consumed. The light air classifier and the secondary air classifier consume 21 and 18% of total energy needs, respectively. Together, the secondary shredder, the light air classifier, the secondary air classifier and the primary shredder represent about 91% of the total amount of energy consumed by the facility.

B.4.5.2 Labor

The number of each type of equipment required to process 3,800 wet tons/day of raw MSW and produce 2,020 dry tons/day of cellulosic materials has been estimated. The detailed results are shown in Table B-11. To meet the specified capacity in 24 hours, the facility needs 4 primary shredders, 4 light air classifiers, 1 magnetic separator, 1 primary air classifier, 1 trommel screen, 2 organic removal jigs, 6 cyclones, 3 secondary shredders, 3 secondary air classifiers, and 2 high-tension separators.

Table B-10.
MSW Sorting/Preparation Facility: Energy Consumption

Equipment	Number of Tons/Day Processed	Energy Requirement (kWh/T)	Energy Consumed (kWh/Day)
Primary Shredder	3,800	5.0	19,000
Light Air Classifier	3,610	7.0	25,270
Magnetic Separator	840	0.1	84
Primary Air Classifier	801	7.0	5,607
Trommel Screens	379.5	0.8	304
Organic Removal Jig	291.8	2.4	701
Cyclone	1,223	0.2	245
Cyclone	404	0.2	81
Secondary Shredder	3,197	13.6	43,480
Secondary Air Classifier	3,125.4	7.0	21,878
Cyclone	2,544	0.2	509
High Tension Separator	2,505	1.0	2,505
Organic Removal Jig	582	2.4	1,397
Total	—	—	121,061*

* The amount of energy consumed by scales, storage, loaders, and conveyors is not included.

Table B-11.
Equipment Required to Process 3,800 Tons/Day (TPD) of Wet Raw MSW to Produce 2,020 Dry TPD of Cellulosic Material

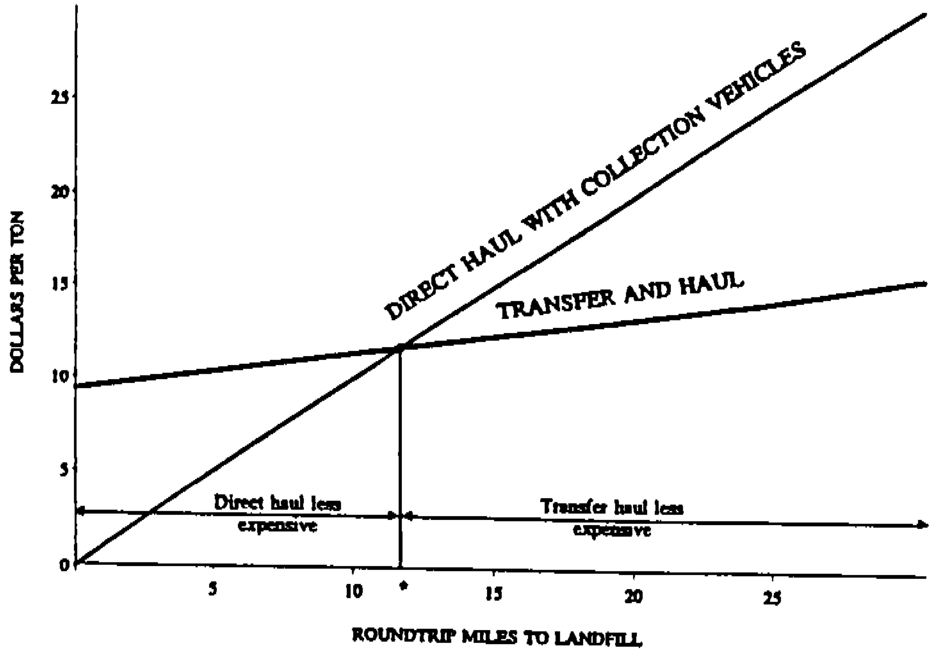
Equipment	Capacity Tons/hour	Number of Tons Processed in TPD	Number of Pieces of Equipment
Primary Shredder	91	3,800	4
Light Air Classifier	73	3,610	4
Magnetic Separator	91	840	1
Primary Air Classifier	73	801	1
Terminal Screens	57	380	1
Organic Removal Jig	260	292	1
Cyclone	75	1,223	2
Cyclone	75	404	2
Secondary Shredder	91	3,197	3
Secondary Air Classifier	73	3,125	3
Cyclone	75	2,544	2
High Tension Separator	75	2,505	2
Organic Removal Jig	260	582	1

B.5 Transportation

B.5.1 Assumptions

B.5.1.1 Tractor Trailer Option

The methods of transporting goods has changed very little over the past decade, therefore all assumptions made for 1990 also apply for the year 2000. It is assumed that any transportation beyond a distance of 25 miles, where rail or barge are either unavailable or uneconomical, is done via a tractor trailer (see Figure B-10).[17] These trucks are assumed to use diesel fuel with an average fuel economy of 5.3 miles per gallon in 1990 and 5.7 in 2000. The average empty tractor-trailer has 9,300 lbs. on the steering axle, 18,700 lbs. on the twin axles under the kingpin, and 12,200 lbs. on the final set of axles in the rear. Assuming the maximum allowable Gross Vehicle Weight (GVW) is 80,000 lbs. and the maximum Axle Weight (AW) is 34,000 lbs. (provided a minimum distance of 36 feet separates the twin axles), the maximum legal payload becomes 39,800 lbs., or 20 tons.[18]



Source: Brown, Michael D. et.al., Solid Waste Transfer Fundamentals, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1981, p.4.

Figure B-10. Break Even Analysis - Transfer versus Direct Haul

There are also off-highway vehicles used in the handling of MSW during the transportation cycle, where they are used to load tractor-trailers, fill compactors, and separate materials. These vehicles also use diesel fuel and their emissions are dependent on the engine power output and the amount of time the machine is used per day. Fuel economy data are unavailable.

B.5.1.2 Rail Option[9]

The transport of MSW by rail is assumed to be accomplished via boxcars. The processed MSW at the sorting/preparation facility will be compacted into 30" x 40" x 72" bales weighing 1,500 pounds each. In this case, 112 bales can be loaded into a 60-foot boxcar, resulting in 30 boxcars being required to haul 2,505 tons of MSW/day.

Although the above method of hauling (baling) was chosen, other means, such as containerized waste hauling, exist. Hauling MSW via containers offers many advantages over baling, including containerization reduces labor requirements due to automation, and has fewer potential environmental risks, though it is much more capital intensive.

B.5.2 Transportation Parameters

B.5.2.1 Current Baseline (1990)

B.5.2.1.1 Transport from the Transfer Station to the Sorting/Preparation Facility

It is assumed that there will be a 22 ton/day loss of MSW and water during the collection of the 4,315 tons of MSW/day, resulting in 4,293 tons/day at the transfer station.

To haul the 4,293 tons/day, using an average of 20 ton/load, gives 215 loads/day which needs to be hauled. The average distance between the transfer station and the separation facility is assumed to be 50 miles, therefore, using the emissions factors cited in Table B-6 (Section B.3), the total emissions per day or year can be determined.

B.5.2.1.2 Transport from the Sorting/Preparation Facility to the Ethanol Facility

B.5.2.1.2.1 Tractor Trailer Option

Using the total amount of cellulosic and organic materials needed to support the ethanol facility, 2,505 tons/day (see Section B.4), and dividing it by the 20 ton/load capacity of the tractor-trailer, gives 126 loads/day going to the ethanol facility. Assuming various distances to the ethanol facility, and again, using the emissions factors in Table B-6 (Section B.3), the exhaust emissions per day or year can be determined.

B.5.2.1.2.2 Rail Option

Assuming the separation facility is located on a rail line, MSW will be baled at the facility and loaded into boxcars with integrated toolcarriers. If an average of 84 tons of MSW are hauled per boxcar, then 30 boxcars are required to transport 2,505 tons per day. One standard

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9 The information contained in this section is based on conversations with and communications from Robert A. Brook, Manager of Solid Waste Products for CP Rail Intermodal Freight Systems.

locomotive could haul the 30 railcars exclusively in one trip, or the boxcars could be attached to a train which already travels the route.

B.5.2.2 The Year 2000 Time Period

B.5.2.2.1 Transport from the Transfer Station to the Sorting/Preparation Facility

It is assumed that there will be a 20 ton/day loss of MSW and water during the collection of the 3,840 tons of MSW/day, giving 3,820 tons/day at the transfer station.

To transfer the required 3,820 tons/day, using a maximum load of 20 ton/load, gives 191 loads/day which needs to be hauled. Assuming the average distance between the transfer station and the separation facility is 50 miles, the total emissions per day or year can be determined.

B.5.2.2.2 Transport from the Sorting/Preparation Facility to the Ethanol Facility

B.5.2.2.2.1 Tractor Trailer Option

Using the total amount of cellulosic and organic materials needed to support the ethanol facility, 2,505 tons/day (see Section B.4), and dividing it by the 20 ton/load capacity of the tractor-trailer, gives 126 loads/day going to the ethanol facility. Assuming various distances to the ethanol facility, and using the emissions factors determined by NREL, the exhaust emissions per day or year can be calculated.

B.5.2.2.2.2 Rail Option

If the separation facility is located on a rail line, baled MSW will be loaded into boxcars by integrated toolcarriers at the facility. Assuming an average load of 84 tons of MSW per railcar, 30 boxcars would be required to haul 2,505 tons of MSW per day. If a dedicated train was used to haul this amount of MSW, one standard locomotive is assumed to be needed, or the boxcars could be attached to a train already using the route, which would require an additional locomotive.

B.5.3 Inputs

B.5.3.1 Current Baseline (1990)

B.5.3.1.1 Energy

Energy requirements for rail and highway vehicles are given below. The requirements for off-highway vehicles are discussed in Section B.9.

B.5.3.1.1.1 Tractor Trailer Option

The fuel economy of tractor trailers was determined by dividing the density of #2 diesel fuel, 7.08 lb/gal, by the brake specific fuel consumption, 0.50 lb fuel/bhp-hr, and the vehicle efficiency of 2.69 bhp-hr, to arrive at 5.3 miles/gallon.

B.5.3.1.1.2 Rail Option

The average energy consumption of a diesel-powered locomotive was assumed to be 434 Btu/ton-mile. The amount of fuel consumed during hauling can be determined by dividing 434 by the 128,700 Btu/gal, energy content of #2 diesel fuel, to get 0.0034 gal/ton-mile, then multiplying this by the weight hauled and by the distance traveled.

B.5.3.1.2 Labor

B.5.3.1.2.1 Tractor Trailer Option

The labor required to haul the MSW between the transfer station and the separation facility, or between the separating facility and the ethanol facility can be assumed to be approximately equal to the number of trucks required, since there is usually one driver per truck. However, there will be some workers at both the transfer station and the separation facility operating wheel loaders and compacting equipment.

B.5.3.1.2.2 Rail Option

The transfer of MSW via rail requires 3 operators per train on a main rail line and 2 operators per train on a branch line. Additional personnel (undetermined) will be needed for maintenance on the trains and switching operations at the separation facility and at the ethanol conversion facility.

B.5.3.2 The Year 2000 Time Period

B.5.3.2.1 Energy

B.5.3.2.1.1 Tractor Trailer Option

The average fuel economy of tractor trailers was found by using the same method as in Section 5.3.1.1.1, except the brake specific fuel consumption was assumed to be 0.46 lb fuel/bhp-hr, giving a fuel economy of 5.7 miles/gallon.

B.5.3.2.1.2 Rail Option

Due to the relatively small changes in the fuel economy of locomotives in recent years, the average fuel economy of locomotives for the year 2000 is assumed to be the same as it was in

1990: 0.0034 gal/ton-mile. By multiplying this by the tons of MSW being hauled and the distance traveled, the amount of fuel consumed can be determined.

B.5.3.2.2 Labor

B.5.3.2.2.1 Tractor Trailer Option

Again, the labor required to haul MSW is largely dependent on the number of trucks required, with some additional workers needed to operate equipment to load the trucks.

B.5.3.2.2.2 Rail Option

As assumed in the year 1990, 3 train operators are required per train that operates on a main rail line, and 2 operators are required per train on a branch line. Additional workers will be needed for maintenance on the trains, as well as switching operations at the separation facility and at the ethanol facility.

B.6 Environmental Overview

B.6.1 Transportation

The movement of MSW for a waste-to-ethanol pathway would utilize, for the most part, the existing MSW transportation infrastructure. Therefore, there may be little additional environmental or health and safety impact associated with the transporting of MSW from curbside, and to the sorting/preparation facility than that which exists for the current methods of MSW disposal. A change in emissions and environmental impacts, will occur due to a change in the transportation mode (i.e., rail) and the added distance to the conversion facility. A summary of the types of emissions and other environmental impacts, as well as health and safety issues, associated with current MSW handling and transportation are summarized below.

B.6.1.1 Emissions

Sections B.7 and B.9 detail the exhaust emissions associated with the collection, handling, and transportation of raw and processed MSW. Air emissions have been estimated for all steps of the cycle, although as mentioned above, only a portion of these emissions are truly applicable to the MSW-to-ethanol energy cycle.

B.6.1.2 Other Environmental Impacts

Although the total amount of MSW handled will not increase as a result of the waste biomass to ethanol process, there will be additional handling and hauling requirements. More trucks may be required and additional miles may be traveled to haul the MSW between the transfer station and the separation facility and then to the conversion plant. If the rail option is chosen for transportation of the processed MSW between the sorting/preparation and conversion facilities, it would result in different and fewer environmental impacts than the tractor trailer option.

The net increase in trucks and hauling miles traveled will result in a number of environmental impacts. These will include increases in the following solid waste materials: used truck tires, used batteries, and other truck parts. In addition, the following liquid-based wastes will increase: used oil, coolants and other required fluids. Finally, there will be an increase in non-material impacts such as: truck traffic (congestion and wear and tear on area roads) and noise levels. These factors will be affected by the maintenance of the trucks, the area road system, driving habits, and other variables.

The rail option would result in less exhaust emissions and fewer of the above-mentioned environmental impacts associated with hauling the MSW by tractor-trailer, however it would introduce some new impacts. Transporting the processed MSW by rail would require more off-road equipment for baling, loading and unloading the MSW to and from boxcars. These vehicles and equipment would have additional environmental impacts associated with material requirements, safety concerns, and solid waste generation, as well as air emissions. Additional environmental concerns associated with the rail option include potential boxcar leakage and odor.

B.6.1.3 Health and Safety

Most of the injuries occurring during the curbside collection of MSW can be attributed to the lifting requirements and accidents involving the compactor mechanisms of the collection vehicles. Sanitation workers are exposed to additional health risks from the exhaust of the trucks. Workers empty refuse containers into the back of the trucks where they are exposed to carbon monoxide and particulate matter emissions. Compactor mechanisms and the dumping of garbage also create large amounts of dust which irritates mucous membranes and respiratory tracts.[19]

Also, discarded volatile or flammable liquids may explode or splash during compaction, causing eye, skin, and respiratory injuries and irritations. Lastly, driver visibility can be poor in refuse collection trucks increasing the risk of accidents.

Additional safety concerns include potential highway accidents involving tractor-trailers hauling MSW. For the rail option safety concerns associated with normal railroad operations will need to be considered for transporting the processed MSW to the conversion facility.

B.6.2 Transfer Station

A summary of the types of emissions and other environmental impacts, as well as health and safety issues, associated with current MSW transfer stations are summarized below. Transfer stations would also utilize the existing MSW transportation infrastructure. Therefore, there would be no additional environmental or health and safety impacts associated with the transfer stations, than that which exists for the current methods of MSW disposal.

It should be noted that by the year 2000 many landfills in the Chicago and Cook County areas are expected to reach capacity and close, requiring MSW to be transported longer distances which will probably require additional transfer station facilities. New transfer stations may be built (often at closed landfill sites) and/or existing transfer stations may be modified to increase their handling capacity. Thus, the environmental impacts associated with the construction or modification of transfer stations would cause construction-related environmental impacts, e.g., air emissions, dust and solid waste generation, noise, and traffic. Once these facilities are functional, additional environmental impacts from facility operations will occur.

B.6.2.1 Emissions

Major emissions associated with a transfer station are due to the collection vehicles, tractor-trailer transportation trucks, and off-road vehicles, see Sections B.7 and B.9 for the assessment of these emissions.

Secondary emissions associated with transfer stations will be due to emissions from the fuel sources that supply electricity to the local grid. The main secondary energy consumer at the transfer station is the hydraulic compaction unit. For a detailed description of the emissions from the grid in Illinois, see Table B-17 in Section B.8 of this appendix. It should be noted that data were unavailable for the electricity consumption of the facility itself. Therefore, some energy requirements, e.g., lighting, for the transfer stations are incomplete. However, the electricity consumption data which were not available are considered to be small when compared to the electricity requirements for the hydraulic compaction unit.

B.6.2.2 Other Environmental Impacts

B.6.2.2.1 Air

Fugitive dust generation due to loading, unloading, and processing of MSW can be a significant, but localized, air quality concern. Dust control measures include: enclosed building, fabric filter dust control devices, water mist sprayers, local respirators to reduce inhalation, and daily housekeeping routines.[20] A more detailed treatment of these emissions and control technologies is given in Section B.8.

B.6.2.2.2 Water

The only water utilized in the transfer station is in the washing down of facility and equipment which is not considered a significant source of water pollution.[21]

B.6.2.2.3 Odors

Mixed MSW is produced, transported, and stored in an environment conducive to objectionable odors. Generally, the transfer station is unloaded each day, which limits odors. Additional odor minimization techniques include daily sweeping and weekly steam cleaning of floors, walls, and equipment.

B.6.2.2.4 Noise

The noise impacts that occur at a transfer station are due to vehicle loading and unloading, and operation of the compactors. This noise can be reduced by performing all of these operations within the enclosed structure. Occupational Safety and Health Administration (OSHA) standards dictate that noise inside the transfer station structure cannot exceed 90 decibels for a period of eight hours.[22]

B.6.2.2.5 Traffic

Depending on the neighboring land uses and the volume of MSW handled by the transfer station, traffic congestion and noise can be significant. Traffic patterns should be considered in order to minimize impacts on the surrounding land uses.

B.6.2.3 Health and Safety

B.6.2.3.1 Explosion Potential

Some potential exists for the explosion of aerosol cans due to compaction pressures as well as fires and explosions from volatile and flammable substances in the MSW. Careful screening of incoming MSW can reduce this possibility considerably. Installation of a water sprinkler system over MSW receiving, storage, and unloading areas, and sufficient fire hose/water capability should reduce the possible explosive effects substantially.

B.6.2.3.2 Hydraulic Compaction Unit

With any open pit design, there is the potential for a worker to fall in, while MSW is being dumped or compacted. Preventive measures such as warning notices, brightly painting edges of the pit, barricading edges of the pit that are not used by either the front end loader or truck, and safety checks before compaction can reduce the risks. Removal of large pieces of steel before compaction may reduce the risk that the sides of the hydraulic compaction unit could be punctured, potentially causing serious injury.

B.6.2.3.3 Pathogens

Biological contaminants in the air are in the form of aerosols. The microorganisms in the aerosols may occur as single units, as clumps of organisms, or those adhering to dust particles. Two types of infections involving airborne contaminants can be of concern in the handling of MSW at a transfer station. Both are acquired by way of the respiratory tract, but differ as to the part of the body that may be affected. Thus, one type is limited to the respiratory tract, while the second may affect some other part of the body, e.g., gastroenteric tract. These microorganisms, in sufficient density, may cause an infection. An enclosed facility will restrict the dispersion of these organisms and appropriate housekeeping practices should limit these organisms within the facility.

A 1974 study reported that the average bacterial counts ranged from 1200/m^3 (no facility activity) to 4700/m^3 when MSW vehicles were unloading.[23]

B.6.2.3.4 Insects and Vermin

With mixed MSW, the organic wastes that attract insects and vermin are only a small percentage of the total MSW stream (see Section B.2). Thus, the potential for attracting insects and vermin is not great. Furthermore, insects are a health and safety consideration for only 6 months of the year (colder temperatures during the rest of the year keep insect activity to a minimum). Roaches will not be a major consideration in the MSW itself due to their reproductive cycle that ranges from weeks to months. The facility will be more conducive for roach population growth. Housekeeping measures are required to reduce this potential problem.[24]

B.6.3 Sorting/Preparation Facility Operation

The emissions and other environmental concerns from the sorting/preparation facility operation are addressed in Section B.8. It should be noted that the environmental impacts associated with waste-to-ethanol processes may be far less than the impacts associated with current MSW disposal technologies, e.g., landfilling, incineration, and mass burn waste-to-energy (especially when considering the additional environmental benefits from the ethanol end-product replacing gasoline and the potential benefits from recycling materials recovered in the sorting/preparation process). Thus a waste-to-ethanol approach to MSW disposal could potentially result in a net decrease in environmental impacts if instituted in place of current MSW disposal methods.

B.6.3.1 Pre-Operation Phase

Site preparation and construction activities for the sorting/preparation facility may have the potential for localized, adverse air quality impacts and other environmental disturbances.
Short-term, localized impacts from construction equipment emissions are dependent on the type of vehicles, mode and duration of operation and meteorological conditions. Diesel-powered construction equipment impacts local air quality most significantly with respect to nitrogen oxides, and gasoline-powered construction equipment impacts local air quality most significantly with respect to carbon monoxide.

Construction and earthwork operations will increase total suspended particulate (TSP) concentrations. Smaller particles will be dispersed over greater distances, while larger particles will settle out near the source causing a localized problem. Excavated materials (soil, gravel, and rock), if left in open piles, will increase TSP emissions. The level of TSP emissions is dependent on the amount and type of construction being performed, soil parameters (particulate size and moisture content), and local meteorological conditions. Dust emissions can be reduced by as much as 50 percent by watering the construction site. Employing wind breaks and covering dusty site material storage areas will also help reduce fugitive dust emissions.

Increased noise levels could result from heavy construction equipment operations. During later construction phases, noise levels should decrease due to the shielding of the erected structure. Construction noise can be reduced by using equipment meeting OSHA requirements, supplying protective ear muffs for workers, and scheduling activities so that the noisiest pieces of equipment are not run simultaneously.

Traffic congestion can also be increased due to construction-related activities.

B.7 Emissions from Collection Vehicles

B.7.1 Assumptions

B.7.1.1 Current Baseline (1990)

It is assumed that MSW is collected at curbside via diesel powered collection trucks, which not only pick up the waste, but also compact it. The average truck load is 3.5 tons, while the average number of trips/truck is 2.5, and the average miles traveled per trip are 5.0 (Section B.3).

B.7.1.2 The Year 2000 Time Period

The collection trucks in the year 2000 are assumed to be very similar to the vehicles of 1990. The average load per truck and number of trips per truck are again assumed to be 3.5 and 2.5 respectively, while the average collection route is assumed to be 5.0 miles (Section B.3).

B.7.2 Collection Parameters

B.7.2.1 Current Baseline (1990)

- MSW required to be collected to support the ethanol facility (tons/day)	4,315
- Average Truck Load (tons)	3.5
- Average number of trips per day per truck	2.5
- Average total number of loads transported per day	
5 day week	1,726
7 day week	1,233
- Average collection route distance (miles)	5.0
- Average miles traveled per day (miles/day) for collection of required amount of MSW.	
5 day week	8,630
7 day week	6,165
- Fuel consumption (gal/yr)	6,750,675

Given the parameters outlined for 1990 on page B-58, the following table depicts exhaust emissions from collection vehicles in grams per brake-horsepower-hour (g/bhp-hr), grams per mile (g/mile), and tons per year (tons/yr).

Table B-12.
Exhaust Emissions from Collection Vehicles - 1990

Emission	g/bhp-hr	g/mile	Tons/Yr
HC	1.1	46.7	115.9
CO	4.8	203.9	505.9
NO_x	4.8	203.9	505.9
PM	0.5	21.2	52.7
SO_x	0.2	9.6	23.7
CO_2	724.0	30,755.5	76,300.5
VOC	NIL	NIL	NIL
Aldehydes	NIL	NIL	NIL

B.7.2.2 The Year 2000 Time Period

- MSW required to be collected to support the ethanol facility (tons/day)	3,840
- Average truck load (tons)	3.5
- Average number of trips per day per truck	2.5
- Average total number of loads transported per day	
5 day week	1,536
7 day week	1,098
- Average collection route distance (miles)	5.0
- Average total miles traveled per day for collection of required amount of MSW	
5 day week	7,680
7 day week	5,490
- Fuel consumption (gal/yr)	6,011,550

Table B-13, provides exhaust emissions given off by collection vehicles for the year 2000.

Table B-13.
Exhaust Emissions from Collection Vehicles - 2000

Emission	g/bhp-hr	g/mile	Tons/Yr
HC	1.0	46.2	102.0
CO	3.0	138.5	306.0
NO_x	3.8	175.5	387.6
PM	0.1	3.7	8.2
SO_x	0.2	9.6	21.1
CO_2	666.1	30,755.5	67,946.5
VOC	NIL	NIL	NIL
Aldehydes	NIL	NIL	NIL

Comparing Table B-12 and Table B-13 shows a substantial reduction in all exhaust emissions in the year 2000. These reductions are due partly to the lower exhaust emissions of the trucks in the year 2000 and partly to the decrease in the number of loads of MSW transported per day. The reduction in the number of loads transported per day was due to increased efficiencies of the MSW handling equipment at the sorting/preparation facility.

B.8 Environmental Emissions and Concerns during MSW Sorting/Preparation Process

B.8.1 Assumptions/Rationale

B.8.1.1 Assumptions

Any waste handling and sorting process emits a variety of pollutants that appear in facility emissions, effluents, and sludge residues. The sources of contaminants which cause these pollution concerns are due to chemicals in consumer products, chemicals added to the waste stream to facilitate processing, and chemical compounds created during waste processing.

No waste handling process can be controlled perfectly, thus a variety of unwanted organic and metallic compounds can be created unintentionally and/or emitted during the process.

B.8.1.2 Rationale

Compared to other solid waste management alternatives, MSW sorting/reclamation operations conceptually present negligible potentially adverse environmental impacts. The only emissions of specific concern are particle concentration, particle size, and trace metal concentration. The data from trace metal analyses of particulates collected from today's sorting/preparation plants, indicate that the amounts of toxic metals are below their respective threshold limit values (TLV's).[10] The sample closest to TLV had a lead content of 0.018 mg/Nm^3, compared to a TLV of 0.150 mg/Nm^3 or approximately a factor of 10 below the TLV.

Chemicals that may cause potential pollution problems during waste handling processes are discussed below.

B.8.1.2.1 Heavy Metals

Lead, cadmium, and mercury are heavy metals generally found in a wide variety of consumer products. They are intentionally used in varying amounts in many consumer products made from metals, paper, plastic, rubber, and leather, as shown in Table B-14. When heavy metals represent a significant fraction of the weight of a consumer product, they can be recycled. But most consumer products only contain a small quantity of heavy metals which are not recovered for economic reasons. An example of contamination is the presence of lead and cadmium in paper (ink) and wood products. Since these metals are frequently found in soils in concentrations of up to 200 parts per million (ppm) for lead and 7 ppm for cadmium, they are taken up by trees as they grow. Heavy metals are released in the dust generated by sorting/reclamation processes. However, their environmental impact is generally considered to be weak, since the amounts released are below their respective TLV's. Table B-15 shows the measured quantities of heavy metals at two MSW facilities where handling, sorting and preprocessing methods such as paper baling and glass crushing occur.

B.8.1.2.2 Chlorine and Sulfur

Chlorine and sulfur are intentionally used to make a number of consumer products, including: chlorine in PVC plastics and insulation, bleached paper products and textiles, and sulfur in tires, cutting oils, and battery acids. Chlorine is in table salt, and hence appears in food waste. Both chlorine and sulfur traces are also found in fuels such as oil and coal, which provide the energy needed to process the waste handling and sorting plant. Some examples of the emission rates of chlorine and sulfur during thermal waste management processes such as incineration, and metals and glass recycling are shown in Table B-16.

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[10] Threshold limit values (TLV's) are from the American Conference of Governmental and Industrial Hygienists.

Table B-14.
The Use of Heavy Metals in Consumer Products

Heavy Metal	Used in:
Cadmium	- metal coatings and plating for white goods - electronics and fasteners - many types of color pigments for plastics, paints and printing inks
Lead	- paints for rustproofing - paints for electrical stability in PVC insulation for wire and cable - bottle caps - contact base of incandescent light bulbs
Mercury	- fluorescent lights - zinc-carbon and alkaline batteries - power control switches for lights and thermostats - mildew-proofing paints

B.8.1.2.3 Organic and Chlorinated Organic Compounds

These compounds are found in many consumer products due to their intentional use in large and small amounts. When used in large amounts and not mixed with other materials, organic and chlorinated organic compounds can be recovered through recycling. A well known example of recoverable materials are paper and plastics. However, most consumer products contain very small amounts of organics and chlorinated organic compounds. These include toluene in inks, formaldehyde in particle board and glues, chlorobenzene in cleaners, methylene chloride in spray propellants, and numerous other compounds used in making paints, solvents, etc. The small amounts and wide variety of these compounds make them nonrecoverable.

Table B-15.
Heavy Metal Releases from MSW Sorting/Preparation Facilities

Uncontrolled Air Emissions	Maximum		Minimum	
	PPM	10^{-3} lbs/hr	PPM	10^{-3} lbs/hr
Cadmium (Cd)	452	.019	141	.0048
Chromium (Cr)	928	.048	93	.0096
Lead (Pb)	3570	.150	178	.0096
Mercury (Hg)	330	.014	18	.0012
Nickel (Ni)	7647	.260	333	.0140
Total particulate	105.		34.	

Residues and Discarded Materials	Heavy Metals (mg/kg)				
	Cd	Cr	Pb	Hg	Ni
Rubber	8.6	35.	83.	<.04	<5.
Yarn (red)	<.6	3.5	10.	.08	3.1
Assorted metals	28.	510.	540.	.05	<60.
Bottle caps	25.	800.	260.	<.3	150.
Glass	1.0	260.	38.	<.04	55.
Hard plastic	<.2	<.2	<.2	<.04	<5.
Soft plastic	12.	53.	190.	.11	.94
Black/white paper	.31	2.5	11.	.04	4.2
Colored paper	<.2	8.0	17.	.14	<2.
Cardboard/wood	<.3	2.6	7.6	.07	1.9

Source: Visalli, Joseph R., "The Similarity of Environmental Impacts From All Methods of Managing Solid Wastes," Journal of Environmental Systems, Volume 19(2), p. 155-170, 1989-90.

Table B-16.
Chlorine and Sulfur Compounds Generated During Thermal Waste Management Processes

Process	Uncontrolled Pollutant Generation Rate
Incineration	3.9 lbs HCL/hr/ton-hr
Incineration	3.4 lbs SO_2/hr/ton-hr
Secondary aluminum	1.7 lbs HCL/hr/ton-hr
Secondary aluminum	1.8 lbs SO_2/hr/ton-hr
Secondary lead	72 lbs SO_2/hr/ton-hr

Source: Visalli, Joseph R., "The Similarity of Environmental Impacts From All Methods of Managing Solid Wastes," Journal of Environmental Systems, Volume 19(2), pp. 155-170, 1989-90.

B.8.2 Emissions and Concerns

When energy and material resources are extracted, processed, and converted from municipal solid waste, the increased number of handling and conversion steps results in new impacts on the environment that require new and more efficient pollution control methods. These potential environmental impacts affect the internal as well as the external environment of a MSW sorting/preparation facility and can influence air and water quality, noise and odor levels, aesthetics and the potential for explosions.

B.8.2.1 Emissions Factors from Electricity Consumption

The energy consumption for each step of the MSW sorting/preparation facility process flowchart was estimated and presented in Section B.4 of this study. The shredder and air classifiers were found to be the most energy intensive equipments of this process. Although emissions from electricity production are considered a secondary environmental impact, the emissions factors to produce the electricity needed to run the plant have been estimated for each equipment/step. The results are shown in Table B-17.

B.8.2.2 Air Releases

Dust and stack emissions are the two major air quality problems caused by MSW handling facilities. Since the processing model presented in Section B.4 does not require incineration, this discussion will be limited to dust generation and control.

Table B-17.
MSW Sorting/Preparation Facility:
Per Day Energy Consumption/Electricity Emissions

Equipment	Number of Tons Processed (T/day)	Energy Requirement (kWh/T)	Energy Consumed (kWh/day)	Electricity Consumption Emissions During Separation/Processing of MSW (lb/day)			
				SO_2	NO_x	CO_2	PM-10
Primary Shredder	3,800	5.0	19,000	91.96	95.00	1,737,607.00	2.19
Light Air Classifier	3,610	7.0	25,270	122.31	126.35	2,311,017.30	2.91
Magnetic Separator	840	0.1	84	0.41	0.42	7,682.05	0.01
Primary Air Classifier	801	7.0	5,607	27.14	28.04	512,776.97	0.64
Trommel Screens	379.5	0.8	304	1.47	1.52	27,801.71	0.03
Organic Removal Jig	291.8	2.4	701	3.39	3.51	64,108.55	0.08
Cyclone	1,223	0.2	245	1.19	1.23	22,406.00	0.03
Cyclone	404	0.2	81	0.39	0.41	7,407.69	0.01
Secondary Shredder	3,197	13.6	43,480	210.44	217.4	3,976,376.40	5.00
Secondary Air Classifier	3,125.4	7.0	21,878	105.89	109.39	2,000,808.70	2.52
Cyclone	2,544	0.2	509	2.46	2.55	46,549.58	0.06
High Tension Separator	2,505	1.0	2,505	12.12	12.53	229,089.77	0.29
Organic Removal Jig	582.1	2.4	1,397	6.76	7.00	127,759.84	0.16
Total	—	—	121,061	585.93	605.35	11,071,392.00	13.93

* The amount of energy consumed by scales, storage, loaders and conveyors is not included.

Source: Energy Information Administration, Electric Power Annual, January 1991 -- Emissions data based on Illinois grid fuel sources of 59.0% nuclear, 40.3% coal, 0.4% gas; 0.3% fuel oil and minimal hydro. Factor used in this analysis in lbs/kWh were: SO_2 = .00484, NO_x = .00500, CO_2 = 91.453, and PM-10 = .000115.

Any facility receiving and/or processing MSW will generate dust; a system like the one presented in our model cannot be immune. Significant dust generators include conveyors, shredders, air classifiers and cyclones. These types of equipment generate significant amounts of paper, plastic and metal dusts. The environmental impact from dust emissions can be significantly minimized by today's technologies. Operations usually are conducted indoors where ventilation and localized dust suppression measures are taken as required. Where greater amounts of dust are likely to be experienced, more sophisticated ventilation and collecting devices are typically used, such as cyclones and fabric filters. The quantity of particulate emissions from a given cyclone will depend on the dimensions of the cyclone and the velocity of the airstream. Typical large-diameter cyclones found in industry will only effectively collect particles greater than 40 micrometers in diameter. If baghouses or fabric filters are used in addition to the cyclone, particulate emissions will be negligible. This is confirmed by the highest particulate concentration reading at one of today's facilities, with a reading of 6.617 mg/Nm^3 which is approximately 66 percent of the nuisance dust TLV of 10 mg/Nm^3.

As discussed earlier, paper and plastics contain toxic materials like lead, cadmium and chlorine (PVC). This emphasizes the need to include a dust control device in the scheme. Dust control measures include complete dust collection systems with fabric filter dust control devices, water-mist sprayers for shredding equipment, cyclones, respirators and other devices to reduce dust inhalation, and daily housekeeping of facility premises. Total and respirable particles should be monitored at worker stations to assure that levels are within Occupational Safety and Health Administration (OSHA) standards of 5 mg/m^3.

B.8.2.3 Water Releases

The only significant water usage occurs in the organic removal jig. In most installations, water requirements amount to 1,500-2,500 gal/ton of MSW. Although a portion of this water is recycled, some of it will be discarded. This wastewater flow contains dissolved metals and chlorine. The dissolved metals include lead from inked paper. Process wastewater must meet the standards set by the National Pretreatment Standards before being discharged into the municipal wastewater system. These standards are determined on a site-specific basis and depend on the capabilities of the local water treatment plant to handle various pollutants. Prior to discharging this wastewater into a municipal sewer system, usually only minimal treatment, such as sedimentation and total adjustment, is required. If the effluents are discharged into public waterways, more extensive treatment and permitting is necessary.

None of the processes in the sorting/preparation facility require water of high temperature, thus no thermal discharges would occur.

There will be increased stormwater runoff from the impervious areas of the facility. However, this runoff would not be contaminated with waste materials because waste materials will be stored in an enclosed area with a drainage system leading to a wastewater treatment plant.

B.8.2.4 Noise

Some of the equipment used in a MSW sorting/preparation facility are considered significant noise generators. Those include shredders and high speed fans. Noise levels higher than 90 decibels have been measured inside resource recovery facilities. However, in most cases, these levels do not occur where operators would be subjected to them for periods exceeding those prescribed by OSHA regulations. In the cases where an operator would be subjected to excessively high levels over extended periods of time, ear protection devices have proven to be sufficient mitigating equipment. Also, walls can be constructed around the shredder for noise suppression.

B.8.2.5 Land Use

The facility is assumed to be located on a 12-acre site. If the facility is sited near a roadway and/or railway that is suitable to the volume of traffic required by the facility there should be little conflict with other land uses in the area.

B.8.2.6 Aesthetics

The building facade should be designed and the grounds landscaped to minimize any adverse visual impacts and to ensure compatibility with surrounding land uses. The air classifier is generally the tallest piece of equipment at an MSW management facility and may project above the roofline. This contrasts with the general shape of the MSW facility which has the low profile common to industrial manufacturing buildings.

Additionally, all waste will be handled within an enclosed structure, thus no waste will be visible from outside the facility. Planting trees and shrubbery strategically around the facility will provide added concealment, pleasant visibility, and improved habitat for organisms that may have been disturbed during construction and operation of the facility.

B.8.2.7 Odor Releases

All MSW handling facilities generate odor to some degree. By use of a proper design and operation, odors should not leave the facility. Only a small portion of the MSW arriving at the separation facility will have the potential to contribute odors because a small percentage of this will be organic matter. Odors can be reduced by minimizing storage time, as well as maintaining periodic deodorizing and good housekeeping practices (i.e., daily sweeping and a minimum of weekly steam cleaning of floors, walls, and accessible equipment).

B.8.2.8 Insects and Vermin

The potential for and the methods for prevention of insects and vermin at the sorting/preparation facility are generally the same as for a transfer station. See Section B.6 for this discussion.

B.8.2.9 Health and Safety

All MSW handling facilities which have a shredder are susceptible to explosions. Although shredder explosions are numerous, their causes vary and are often difficult to identify. Materials identified as having caused explosions are common flammable gases or vapors (gasoline, propane, paint thinner, etc.), and commercial or military explosives (dynamite, gunpowder, etc.). Another important hazard that can develop in shredding operations is the high-velocity ejection of hard objects (e.g., rocks and metal) that may result from the impact of the hammers upon the objects.

To reduce the risk of fires and of dust and shredder explosions in a MSW sorting/preparation facility, careful placement of suppression and control devices throughout the processing system is required. Several methods are used to minimize explosion potential. These include: the utilization of explosion suppression systems, the use of a continuous water spray within the shredder to protect against flammable vapor and dust explosions (this also provides a valuable fire protection measure), manually screening input materials, the use of ducts for channeling vented shredder gas out of the building, and the construction of walls around shredders for added protection.

Biological contaminants may become airborne adhering to dust particles. Risk from airborne pathogens will be minimized by basic housekeeping practices and effective ventilation of the facility. Many of the same mitigation measures that are recommended for control of fugitive dust within the facility should also control microorganisms.

Workers should be required to wear gloves while working in the plant. Suitable sanitation facilities for the work force must be provided. Workers should also be required to strictly adhere to basic hygienic practices. Outer clothing worn inside the plant should not be worn outside the plant.

B.9 Transportation Emissions

B.9.1 Assumptions

Two different scenarios are presented for the transport of MSW between the sorting/preparation facility and the ethanol conversion facility. The first assumes that all of the MSW is transported via tractor-trailer vehicles having a maximum legal payload of 20 tons (see Section B.5). The second scenario assumes that all of the processed MSW is baled at the separation facility and hauled by rail to the ethanol conversion facility.

B.9.2 Exhaust Emissions Between Transfer Stations and Sorting/Preparation Facility

B.9.2.1 Current Baseline (1990)

- Total amount of MSW required to be hauled (tons)	4,293
- Average truck load (tons)	20
- Average total number of loads transported per day	
5 day week	301
7 day week	215
- Transport distance (miles)	50
- Average total miles traveled per day for transport of required amount of MSW	
5 day week	15,050
7 day week	10,750
- Fuel consumption (gal/yr)	745,402

Table B-18 provides estimated emissions for 1990 during transport of unprocessed MSW to the sorting/preparation facility.

Table B-18.
Exhaust Emissions from the Transport of MSW - 1990

Emission	g/bhp-hr	g/mile	Tons/Yr
HC	1.1	3.0	12.8
CO	4.8	12.9	55.9
NO_x	4.8	12.9	55.9
PM	0.5	1.3	5.8
SO_x	0.2	0.6	2.6
CO_2	724.0	1,947.6	8,425.0
VOC	NIL	NIL	NIL
Aldehydes	NIL	NIL	NIL

B.9.2.2 The Year 2000 Time Period

- Total amount of MSW required to be hauled (tons)	3,820
- Average truck load (tons)	20
- Average total number of loads transported per day	
5 day week	268
7 day week	191
- Transport distance (miles)	50
- Average total miles traveled per day for transport of required amount of MSW	
5 day week	13,400
7 day week	9,550
- Fuel consumption (gal/yr)	609,219

Using the above factors, Table B-19 details estimated emissions given off during transport of unprocessed MSW to the sorting/preparation facility for the year 2000.

Table B-19.
Exhaust Emissions from the Transport of MSW - 2000

Emission	g/bhp-hr	g/mile	Tons/Yr
HC	1.0	2.7	10.3
CO	3.0	8.1	31.0
NO_x	3.8	10.2	39.3
PM	0.1	0.2	0.8
SO_x	0.2	0.6	2.1
CO_2	666.1	1,795.5	6,900.3
VOC	NIL	NIL	NIL
Aldehydes	NIL	NIL	NIL

The reductions in the amount of emissions in Table B-19 compared to Table B-18 are a result of both cleaner-burning vehicles and a decrease in the number of loads of MSW transported per day. This decrease is due to increased efficiencies in the equipment. (See Section B.4)

B.9.3 Exhaust Emissions Between Sorting/Preparation Facility and Ethanol Facility

B.9.3.1 Tractor Trailer Option

B.9.3.1.1 Current Baseline (1990)

- Total amount of MSW required to be hauled (tons)	2,505
- Average truck load (tons)	20
- Average total number of loads transported per day	
5 day week	176
7 day week	126
- Average fuel economy (mile/gal)	5.3

Table B-20, below, presents emission levels for 1990 given off during transport of processed MSW to the conversion plant.

Table B-20.
Exhaust Emissions from the Transport of MSW - 1990

Miles to Ethanol Facility	Fuel Consumption gal/yr	Emissions (Tons/Yr)					
		HC	CO	NO_x	PM	SO_x	CO_2
50	436,840	7.5	32.7	32.7	3.4	1.5	4,937.5
75	655,260	11.3	49.1	49.1	5.1	2.3	7,406.2
100	873,680	15.0	65.5	65.5	6.8	3.1	9,874.9
125	1,092,100	18.8	81.8	81.8	8.5	3.8	12,343.6
150	1,310,520	22.5	98.2	98.2	10.2	4.6	14,812.4

B.9.3.1.1 The Year 2000 Time Period

- Total amount of MSW required to be hauled (tons)	2,505
- Average truck load (tons)	20
- Average total number of loads transported per day	
5 day week	176
7 day week	126
- Average fuel economy (mile/gal)	5.7

Table B-21 provides estimated emissions in 2000 for transportation of processed MSW to a conversion plant.

Table B-21.
Exhaust Emissions from the Transport of MSW - 2000

Miles to Ethanol Facility	Fuel Consumption gal/yr	Emissions (Tons/Yr)					
		HC	CO	NO_x	PM	SO_x	CO_2
50	401,893	6.8	20.5	25.9	0.5	1.4	4,552.0
75	602,839	10.2	30.7	38.9	0.8	2.1	6,828.0
100	803,786	13.6	40.9	51.8	1.1	2.8	9,104.0
125	1,004,732	17.0	51.2	64.8	1.4	3.5	11,380.0
150	1,205,679	20.5	61.4	77.7	1.6	4.2	13,656.0

Again, the decrease in the exhaust emissions in Table B-22 compared to Table B-20 is the result of both the cleaner-burning vehicles and the decreased number of loads of MSW required to support the ethanol conversion plant in the year 2000. (See Section B.4)

B.9.3.2 Rail Option

B.9.3.2.1 Current Baseline (1990)

- Total amount of MSW required to be hauled (tons/day): 2,505
- Average railcar loading (tons): 84
- Number of railcars transported per day: 30
- Number of diesel locomotives per trains: 1
- Average fuel consumption (gal/ton-mile): 3.4×10^{-3}

Using the above data, exhaust emissions form the transport of processed MSW between the sorting/preparation facility and the ethanol conversion facility are presented in Table B-22.

Table B-22.
Exhaust Emissions From the Transport of MSW - 1990

Miles to Ethanol Facility	Fuel Consumption gal/yr	Emissions (Tons/Yr)					
		HC	CO	NO_x	PM	SO_x	CO_2
50	154,164	1.6	6.5	32.5	0.8	0.5	1,742.5
75	231,245	2.4	9.8	48.8	1.2	0.8	2,613.7
100	308,327	3.3	13.0	65.1	1.6	1.1	3,484.9
125	385,409	4.1	16.3	81.3	2.0	1.4	4,356.1
150	462,491	4.9	19.5	97.6	2.4	1.6	5,227.4

B.9.3.2.2 The Year 2000 Time Period

- Total amount of MSW required to be hauled (tons/day): 2,505
- Average railcar loading (tons): 84
- Number of railcars transported per day: 30
- Number of diesel locomotives per train: 1
- Average fuel consumption (gal/ton-mile): 3.4×10^{-3}

Using the above data, exhaust emissions from the transport of the required amount of processed MSW between the sorting/preparation facility and the ethanol conversion facility, were calculated and are presented in Table B-23.

Table B-23.
Exhaust Emissions From the Transport of MSW - 2000

Miles to Ethanol Facility	Fuel Consumption gal/yr	Emissions (Tons/Yr)					
		HC	CO	NO_x	PM	SO_x	CO2
50	154,164	1.3	4.9	22.8	0.5	0.5	1,742.5
75	231,245	2.0	7.3	34.2	0.7	0.8	2,613.7
100	308,327	2.6	9.8	45.5	1.0	1.1	3,484.9
125	385,409	3.3	12.2	56.9	1.2	1.4	4,356.1
150	462,491	3.9	14.6	68.3	1.5	1.6	5,227.1

B.9.4 Emissions from MSW Handling Off-Highway Vehicles

B.9.4.1 Assumptions

Various types of off-highway vehicles are required at the transfer stations and separation facility to handle the large volumes of MSW required. Wheel loaders are large, rubber-tired vehicles with buckets of various sizes mounted to a hydraulically controlled arm. These diesel-powered machines can be used for pushing, carrying, and stockpiling refuse. Also, integrated tool- carriers can be used for almost all handling of MSW. These vehicles look similar to wheel-loaders, but are slightly smaller, and have several attachments, or tools, which are available that allow the integrated toolcarriers to perform a variety of tasks. Additionally, for the rail option, integrated toolcarriers will be used to load bales of cellulosic feedstock leaving the sorting/preparation facility into railcars for transport to the ethanol conversion facility. It is estimated that the integrated toolcarriers handle 1/2 as much MSW per vehicle as the wheel loaders due to their smaller size. Both wheel loader and integrated tool carrier emissions have been estimated to operate at 75% of the operating period of the facility (transfer of sorting preparation) to allow for down time during scheduled and unscheduled maintenance and refueling.

B.9.4.2 Off-Highway Vehicle Exhaust Emissions at the Transfer Station

B.9.4.2.1 Current Baseline (1990)

For 1990, 4,293 tons of MSW would be handled at the transfer station, which accounts for a loss of 22 tons of MSW per day during transit and handling of the 4,315 tons/day collected, as well as water losses. It has been estimated that 6 wheel loaders and 5 integrated toolcarriers will be required.

It is assumed that the average operating period for the transfer facility is 9 hours/day seven days per week. The emissions for the 6 wheel loaders and 5 integrated toolcarriers are based on a 6.75 hour day (75% operation factor) are presented in Table B-24 and Table B-25.

Table B-24.
Off-Highway Vehicle Exhaust Emissions at the Transfer Station (Wheel Loaders) - 1990

Diesel Fuel Consumption	**187,913 gal/yr**		
Wheel Loaders (6)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	1.0	785.7	2.9
CO	2.7	2,195.0	8.0
NO_x	8.8	7,136.1	25.8
PM	0.8	652.1	2.4
SO_x	0.2	182.3	0.7
CO_2	724.0	586,440.0	2,123.9

Table B-25.
Off-Highway Vehicle Exhaust Emissions at the Transfer Station (Toolcarriers) - 1990

Diesel Fuel Consumption	**63,798 gal/yr**		
Integrated Toolcarriers (5)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	1.0	266.8	1.0
CO	2.7	745.3	2.7
NO_x	8.8	2,422.8	8.8
PM	0.8	221.4	0.8
SO_x	0.2	61.9	0.2
CO_2	724.0	199,100.0	721.1

Table B-24 and Table B-25 are appropriate for either the trucking or rail options for 1990. The off-highway emissions are only at the front end of the transfer station as these vehicles only transfer MSW to the hydraulic pit for tractor-trailer transport.

B.9.4.2.2 The Year 2000 Time Period

Due to higher process efficiencies in the sorting/preparation stage in 2000, only 3,820 tons of MSW is required to be transferred to the ethanol conversion facility (the 3,820 accounts for a loss of 20 tons of MSW and water during the transport of the 3,840 tons of MSW/day by the collection trucks). This reduction in tons results in the reduction of off-highway vehicles. Therefore, 5 wheel loaders and 5 integrated toolcarriers are assumed. The emission factors for both types of vehicles improved from 1990.

The off-highway vehicle operating hours assumed have remained the same, at 6.75 hours/day for seven days per week. The cumulative annual emissions for off-highway vehicles at transfer stations in 2000 is shown in Table B-26 and Table B-27.

Table B-26.
Off-Highway Vehicle Exhaust Emissions at the Transfer Station (Wheel Loaders) - 2000

Diesel Fuel Consumption	**144,067 gal/yr**		
Wheel Loaders (5)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	0.8	540.0	2.0
CO	3.2	2,187.0	7.9
NO_x	6.7	4,495.5	16.3
PM	0.6	382.1	1.4
SO_x	0.2	139.7	0.5
CO_2	666.1	449,604.0	1,628.3

Table B-27.
Off-Highway Vehicle Exhaust Emissions at the Transfer Station (Toolcarriers) - 2000

Diesel Fuel Consumption	58,694 gal/yr		
Integrated Toolcarriers (5)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	0.8	220.0	0.8
CO	3.2	891.0	3.2
NO_x	6.7	1,831.5	6.6
PM	0.6	155.7	0.6
SO_x	0.2	56.9	0.2
CO_2	666.1	183,172.0	663.4

B.9.4.3 Off-Highway Vehicle Exhaust Emissions at Sorting/Preparation Facility

B.9.4.3.1 Entering the Facility

B.9.4.3.1.1 Current Baseline (1990)

The Sorting/Preparation facility is assumed to operate 24 hours/day 7 days/week. Adjusting for the down time of off-highway vehicles for maintenance and fueling, roughly half of the vehicles will be required at the sorting/preparation facility (to move 4,270 tons MSW/day, which accounts for a loss of 23 tons of MSW and water from the 4,293 tons/day at the Transfer Station due to transit and handling), since these vehicles will operate 18 hours/day/vehicle compared to 6.75 hours/day/vehicle assumed at the transfer stations. Therefore, we have assumed that 3 wheel loaders and 2 integrated toolcarriers will be required at the front-end of the sorting/preparation facility for 1990. The emission factors are the same as the ones used for 1990 transfer station off-highway vehicle emissions. Table B-28 and Table B-29 present the total annual off-highway emissions for the front-end of the sorting/preparation facility.

**Table B-28.
Off-Highway Vehicle Exhaust Emissions at the
Sorting/Preparation Facility (Wheel Loaders) - 1990**

Diesel Fuel Consumption	250,551 gal/yr		
Wheel Loaders (3)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	1.0	392.9	3.8
CO	2.7	1,097.6	10.6
NO_x	8.8	3,568.1	34.5
PM	0.8	326.0	3.2
SO_x	0.2	91.1	0.9
CO_2	724.0	293,220.0	2,831.9

**Table B-29.
Off-Highway Vehicle Exhaust Emissions at the
Sorting/Preparation Facility (Toolcarriers) - 1990**

Diesel Fuel Consumption	68,051 gal/yr		
Integrated Toolcarriers (2)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	1.0	106.7	1.0
CO	2.7	298.1	2.9
NO_x	8.8	969.1	9.4
PM	0.8	88.6	0.9
SO_x	0.2	24.8	0.2
CO_2	724.0	79,640.0	769.2

Note: Tables B-28 and B-29 apply to both the tractor trailer and rail options as the MSW enters the sorting/preparation facility.

B.9.4.3.1.2 The Year 2000 Time Period

Again, due to the lower volume of MSW required in 2000, 1 less off-highway vehicle will be required compared to 1990. Two wheel loaders and two integrated toolcarriers are required. The same 18 hours of operation has been assumed. Table B-30 and Table B-31 shows the annual emissions results.

Table B-30.
Off-Highway Vehicle Exhaust Emissions at the Sorting/Preparation Facility (Wheel Loaders) - 2000

Diesel Fuel Consumption	**153,671 gal/yr**		
Wheel Loaders (2)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	0.8	216.0	2.1
CO	3.2	874.8	8.5
NO_x	6.7	1,798.2	17.4
PM	0.6	152.8	1.5
SO_x	0.2	55.9	0.5
CO_2	666.1	179,841.6	1,736.9

Table B-31.
Off-Highway Vehicle Exhaust Emissions at the Sorting/Preparation Facility (Toolcarriers) - 2000

Diesel Fuel Consumption	**62,607 gal/yr**		
Integrated Toolcarriers (2)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	0.8	88.0	0.9
CO	3.2	356.4	3.4
NO_x	6.7	732.6	7.1
PM	0.6	62.3	0.6
SO_x	0.2	22.8	0.2
CO_2	666.1	73,268.8	707.6

B.9.4.3.2 Leaving the Facility

B.9.4.3.2.1 Current Baseline (1990)

B.9.4.3.2.1.1 Tractor Trailer Option

For the trucking option, no off-highway vehicles are required since hydraulic compactors directly load the tractor-trailers.

B.9.4.3.2.1.2 Rail Options

As mentioned in B.9.4.1, the rail option requires balers to compact the cellulosic feedstock, and integrated toolcarriers to load the bales into railroad box cars. Three integrated toolcarriers have been assumed to operate 18 hours per day to load the train, the cumulative annual emissions are shown in Table B-32.

Table B-32.
Off-Highway Exhaust Emissions at the Sorting/Preparation Facility (Toolcarriers) - 1990

Diesel Fuel Consumption	**102,076 gal/yr**		
Integrated Toolcarriers (3)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	1.0	160.1	1.6
CO	2.7	447.2	4.3
NO_x	8.8	1,453.7	14.0
PM	0.8	132.8	1.3
SO_x	0.2	37.1	0.4
CO_2	724.0	119,460.0	1,153.7

B.9.4.3.2.2 The Year 2000 Time Period

B.9.4.3.2.2.1 Tractor Trailer Option

Again, no off-highway vehicle emissions occur since the tractor-trailers are loaded directly by the hydraulic compactors.

B.9.4.3.2.2.2 Rail Option

Three integrated toolcarriers have been assumed since the output of the sorting/preparation facility has remained constant from 1990 to 2000 at 2,505 tons of cellulosic MSW/day. The year 2000 annual emissions for the back-end process of the loading the rail cars is illustrated in Table B-33.

Table B-33.
Off-Highway Vehicle Exhaust Emissions at the Sorting/Preparation Facility (Toolcarriers) - 2000

Diesel Fuel Consumption	**93,910 gal/yr**		
Integrated Toolcarriers (3)	**g/bhp-hr**	**g/hr**	**Tons/Yr**
HC	0.8	132.0	1.3
CO	3.2	534.6	5.2
NO_x	6.7	1,098.9	10.6
PM	0.6	93.4	0.9
SO_x	0.2	34.2	0.3
CO_2	666.1	109,903.0	1,061.4

B.10 References

1. HDR Engineering, Inc., Draft Solid Waste Management Plan for City of Chicago, Volume II, August 23, 1991, pp. 2-1, 2-5, 2-8.

2. City of Chicago, "Needs Assessment Information," factsheet for the development of the Solid Waste Management Plan for the City of Chicago, 1991.

3. HDR Engineering, Inc., Draft Solid Waste Management Plan for City of Chicago, Volume I, August 22, 1991, pg. 1-8.

4. Northeastern Illinois Planning Commission, Solid Waste Needs Assessment for the Cook County Planning Area, June 1991, p. ii.

5. City of Chicago, op. cit.

6. Wolpin, William M., ed., "Specification Catalog 1991," World Wastes, Volume 34, No. 1, January 1991, pg. 110-115.

7. Brown, Michael D., et. al., Solid Waste Transfer Fundamentals, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1981, p. 55.

8. SCS Engineers, Solid Waste Management Plan, Fairfax County Virginia, published by SCS Engineers, Reston, Virginia, June 1991, pp 3-18 to 3-22.

9. Phone conversation with Larry Collings, Manager, Marketing and Public Affairs for the Robbins Resource Recovery Company. When asked whether a facility that was twice as large would need twice as many people, Mr. Collings said that it wouldn't require too many more people. How many people exactly, he couldn't speculate. Thus, since our sorting/preparation facility sorts 3,800 tons/day (2-1/2 times larger than Robbins) and factoring out that the Robbins figure included employees that maintain the incinerator, we estimate that the separation facility characterized here will require 50% more employees (for a total of 135).

10. Edison Electric Institute, Statistic Yearbook of the Electricity Industry - 1989, December 1990.

11. Phone conversation with John Scott, Solid Waste Sales Manager, Shredding Systems, Inc.

12. U.S. EPA Office of Solid Waste, Characterization of Municipal Solid Waste in the United States: 1990 Update, Washington, DC, June 1990.

13. Wolpin, William M., ed., op. cit.

14. Cimino, Joseph A., Health and Safety in the Solid Waste Industry, American Journal of Public Health, January 1975, pg. 39.

15. Ibid.

16. Ibid.

17. Brown, Michael D., et. al., op. cit. pg. 6.

18. Brown, Michael D., et. al., op. cit., pg. 29.

19. Cimino, Joseph A., op. cit.

20. Brown, Michael D., et. al., op. cit., pg. 33.

21. Ibid.

22. Brown, Michael D., et. al., op. cit., pg. 32.

23. Camp, Dresser & McKee, I-95 Energy Resource Recovery Facility Environmental Assessment, April 1986, pg. 2-167.

24. Camp, Dresser & Mckee, op.cit., pp. 3-21 and 3-22.